Electrical Engineering

August
1935

Pacific Coast Convention—Seattle, Wash.—Sept. 27–30, 1935

Published Monthly by the
American Institute of Electrical Engineers

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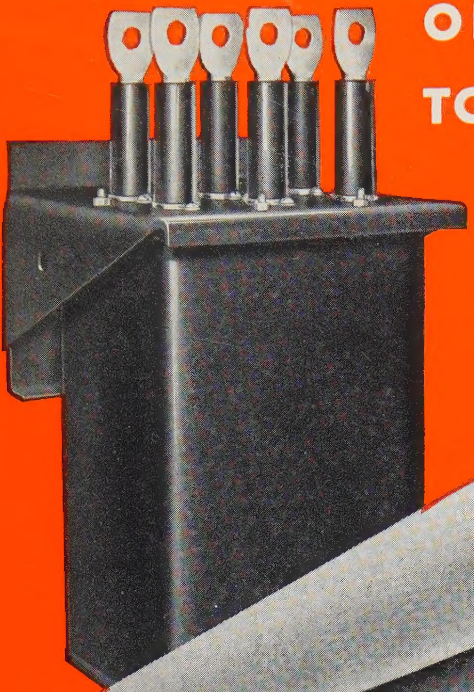

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Front Cover

Seattle, Wash., host city to the Institute's 1935 Pacific Coast convention, August 27–30, as viewed from the city's waterfront

Special Articles

A.I.E.E. Papers

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Discussions

News of Institute and Related Activities . . 891

In This Issue—

REPORTS of the different activities at the Institute's recent successful summer convention at Ithaca, N. Y., June 24–28, have been prepared and made available to the membership. The general features of the convention, including the annual business meeting, presentation of the Lamme Medal, entertainment, and sports included many items of interest (*pages 891–5*). The annual conference of officers, delegates, and members brought forth many illuminating discussions on affairs of importance to the Institute (*pages 898–901*). An innovation this year was the holding of informal round table discussions, called "technical conferences," in addition to the regular technical sessions; these conferences made possible a wide dissemination of information (*pages 901–7*).

ULTRA-HIGH frequencies are particularly useful for radiotelephone communication systems in relatively small areas. In the Hawaiian interisland system frequencies between 30 and 60 megacycles per second are used (*pages 822–8*); in the Puget Sound (Wash.) area, frequencies between 2 and 3 megacycles are used for communication between land and harbor craft (*pages 828–31*). Frequency control for the transmitters used in this type of service is provided conveniently by the use of resonant lines (*pages 852–7*).

REGISTRATION of engineers is a subject of considerable current interest. The principal arguments for registration, which means examination and ratification by legally authorized state boards of engineering examiners, are set forth in detail by Dr. D. B. Steinman, one of the leading exponents of registration (*pages 876–81*). A few additional comments on registration were made by L. W. W. Morrow during the recent summer convention of the Institue at Ithaca (*page 899*). Contributions commenting on Doctor Steinman's address, which was presented at the summer convention, are being received and in so far as possible will be published in the "Letters to the Editor" columns of future issues.

MANUFACTURERS of oil-impregnated paper-insulated cables have made practical use of insulation research by applying the findings directly to their manufacturing processes. The result—cables of improved and more uniform quality which enable users to obtain more satisfactory operating results and to effect substantial savings at the same time (*page 816–21*).

PHOTOGRAPHS of all officers of the Institute who took office August 1, 1935, are reproduced in this issue (*page 897*). The president holds office for one year, the 5 vice presidents for 2 years each, and the 3 directors for 4 years each. In addition to these newly elected officers there are 18 hold-over officers, whose photographs have been given in previous years.

LAST call for the Institute's Pacific Coast convention to be held at Seattle, Wash., Aug. 27–30, 1935, is being made. The schedule of events, technical program, and entertainment and other features were outlined in the July 1935 issue of ELECTRICAL ENGINEERING, pages 783–4. A few additional details are given in the present issue (*pages 895–6*).

THE increase in corona losses on high voltage transmission lines due to the grounding of one conductor on a system not having the neutral solidly grounded may affect the operation of Petersen coils. Tests have been made on a 230 kv line showing the increase in corona losses under certain conditions of operation (*pages 846–7*).

DIESEL-electric motive power is coming into rapidly increasing use on railroads. Although the further substitution of Diesel power for steam power is indicated, performance characteristics must be considered for each type of application. In switching service, the Diesel engine has an immediate field of application (*pages 863–8*).

MEASUREMENTS of the time lag of spark-over of sphere gaps made with a newly developed instrument show that spark lags fall into 3 distinct domains. A study of the data has made possible a better understanding of the theory of sparkover (*pages 868–76*).

PLANS for accrediting engineering schools in New England and the Middle Atlantic states have been completed by the Engineers' Council for Professional Development, which intends to extend the accrediting procedure throughout the entire country as soon as feasible (*page 895*).

A NEW design of coupling capacitors for conducting high frequency carrier current to high voltage power transmission lines has been developed. By combining 1 to 4 units in series, the capacitor may be used on 69, 138, 230, or 287 kv circuits (*pages 848–52*).

MANY problems in voltage regulation on distribution systems can be solved most economically by installing regulating devices on portions of the system beyond the substations; this is particularly true where load growth is nonuniform (*pages 832–7*).

CORRELATION of laboratory tests with the effects of lightning on electric power lines and equipment shows that lightning currents may be as high as 150,000 to 200,000 amperes with durations of from 40 to 100 microseconds (*pages 837–43*).

RESEARCH investigations in the field of radio communication indicate that rapid progress has recently been made in this field. A bibliography totaling 104 items has been compiled, giving references to the principal articles in this field (*pages 843–6*).

5 NEW elementary particles of matter were discovered by physicists during the 3 years 1931–34; these are discussed in this issue by a noted authority (*pages 808–16*).

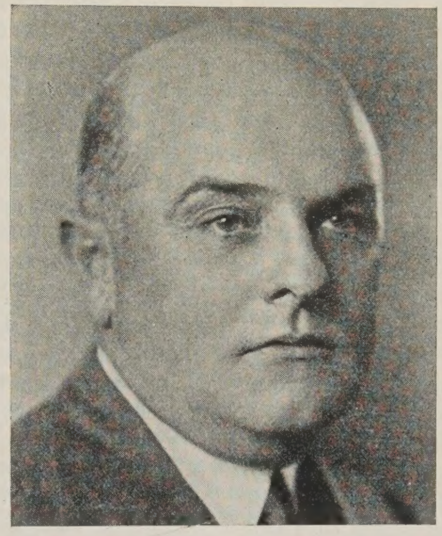
AN instrument has been developed that is said to offer a better means of correlating radio interference measurements with interference effects (*pages 857–62*).

A Message From the President

Fellow Members of the American Institute of Electrical Engineers—

WHEN men find themselves the recipients of honors which their associates have bestowed upon them, I am sure that the emotion is always that which I feel as I endeavor to express my appreciation for having been chosen to serve the Institute as its president for the ensuing year. That feeling is one of wishing that you might fully comprehend what is in the heart of one newly elected to the highest office of our Institute and not be misled by the utter inadequacy of words to convey thought.

The emotion is one of mingled elation and humility. I could not receive so high an honor at your hands without being lifted up in spirit, but at the same time, there comes, with the realization of the obligation, a hope that I may be privileged to sustain that high quality which has ever characterized the Institute and its work and by which it has been known throughout the world.



Edward Barnard Meyer
A.I.E.E. President 1935–36

It has been my pleasure and privilege to have had direct contact with many activities which make up the routine of the Institute's every day work. Such duties as have been assumed throughout the years, on matters concerning the technical, financial, and administrative activities of our society's life, have each in turn brought their own reward for whatever of time and effort was given. For the most part, recompense has come out of the association with so many of the members, representing all phases of our professional life and all branches of industry.

It is with a very sincere feeling of gratefulness for this experience, for these opportunities to feel the pulse of things that concern us, that I look forward to the coming year and accept the responsibility for conducting as ably as I can the affairs of the Institute.

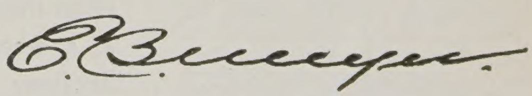
The American Institute of Electrical Engineers like all similar professional groups has passed through trying times and is not yet in all respects free of care. New problems confront us, many perhaps because of the fact that horizons are widening through effort and scientific work of our own and allied professions. But such conditions bring greater opportunities for service by people in all walks of life and I am proud of the extent to which engineers are equipped and ready to take the lead in all forward-looking movements.

Co-operation, then, on the part of all of those who understand the true significance of fellowship in such an engineering fraternity as the Institute, which represents but one aspect of our great engineering profession is vital—if our aims and purposes, our ideals, are to be realized.

The contribution that has been made by those who have been identified with the Institute from the time of its founding more than 50 years ago is today immeasurable. The services of these men have consistently furthered those things for which the Institute has always stood professionally and culturally.

Accomplishment in such an institution is the more permanent if consistently onward and upward with ideals held high regardless of the stress under which we have to carry on. It would, therefore, be my wish that with your help and counsel, throughout the coming months, we may find at the end of the year that we have placed on the Institute's curve of progress a point which not only maintains the slope of the curve at the correct value but reaches so high as to be beyond our greatest hope. There is no failure except in no longer trying.

I am confident that with your co-operation the affairs of the Institute will be conducted in such a manner that the end of the year will mark another period of distinguished service to the engineering profession.



The Newly Discovered Elementary Particles

By KARL K. DARROW, Associate A.I.E.E.
Bell Telephone Laboratories, Inc., New York, N. Y.

During the 3 years following the discovery of heavy hydrogen in the latter part of 1931, 4 additional elementary particles of matter lighter than the alpha particle (nucleus of the ordinary helium atom) have been discovered where only 2 were known previously. This is considered extraordinary even for the present rapid pace of physics which sometimes requires physicists to revise their fundamental concepts of matter almost overnight. These 5 newly discovered particles formed the subject matter of a highly interesting and instructive address delivered recently by Doctor Darrow at a meeting of the Institute's New York Section; the essential substance of this illuminating address is presented herewith.

AS LATELY as 4 years ago—up to the autumn of 1931, to be precise—the only material or electrical particles recognized to be smaller than the known chemical atoms were the nuclei of these very atoms, and the negative electrons which link themselves with these nuclei to form the atoms or which alternatively wander as free corpuscles through metals or gases or empty space. In respect of mass, the lightest of these particles is the negative electron, and after it follow the nuclei of the known atoms in order of increasing weight. Thus as lately as 1931, the table of the known subatomic particles in order of increasing mass began in this way:

1. The negative electron.
2. The nucleus of the ordinary hydrogen atom, called the "proton."
3. The nucleus of the ordinary helium atom, called the "alpha particle."

After the alpha particle followed the nuclei of all the known isotopes of the heavier elements, already very abundant and now more numerous yet; before the alpha particle, however, came only the negative electron and the proton. Three short years changed this situation to a degree extraordinary even for the present rapid pace of physics. By the summer of 1934, the 2 kinds of corpuscle which were known to precede the alpha particle in the smallness of their mass, and therefore almost certainly outrank it in their simplicity, were joined by a host of no fewer than 5 others. The third member of the foregoing list is the eighth of the contemporary table.

Since the word "elementary" may be taken to mean "simple," or "indivisible," or "ultimate," I hasten to make clear that I am using it in no such sense. It is altogether probable that some of these corpuscles, notably the electrons, are truly ultimate and indivisible (and yet, such a statement as this can never be perfectly proved!); but it is certain that others had best be considered composite, while for yet others—the proton and the soon to be mentioned neutron—the question is unsettled and acute. We may, however, believe with great confidence that some of these bodies are the ultimate particles out of which electricity and matter are built, while the rest are the simplest possible structures which can be built out of the ultimate particles. Considered in this light, the members of the latter class are as important for us to study as the members of the former. We are indeed concerned not merely with the ultimate particles as free and independent objects, but also and equally with the laws according to which they attach themselves to one another in forming ordinary matter. To ignore or undervalue these would be as unwise as to ignore the rules of organizing bricks and stones and beams into a building, and devote one's self entirely to measuring the weight and size of isolated beams and stones and bricks with all possible care. Now evidently it is the simplest possible building constructed out of given units of construction, from which we are likely to learn most readily the laws of the combination of these units. The simplest possible structure built out of the fundamental particles of the material world was formerly supposed to be the alpha particle; now it is superseded by several which are apparently still simpler, and all of them together merit our attention as much as do the particles which are still supposed to be the ultimate units of their structures.

Before writing down the list of the particles with which we shall have to do, it is desirable to recapitulate some rather dry information about the charges and the masses of atomic nuclei and the notation for expressing them. A chemical element may, and usually does, have more than one kind of atom. What all the atoms of a given element possess in common is a characteristic value of the nuclear charge. This value is positive in sign, and equal in magnitude to some integer multiple Ze of the electron charge e. The integer Z is called the "atomic number" of the element, and is prefixed as a subscript to the chemical symbol thereof, so that ${}_1H$ denotes hydrogen, ${}_2He$ helium, ${}_3Li$ lithium, and so on. What distinguishes the different kinds of atoms of a given element is, that their nuclei differ in mass. Atoms of a particular mass are said to belong to a particular isotope of the element. The customary unit of mass in this field is $^1/_{16}$ *of the mass of an atom of the commonest isotope of oxygen* (it is about $1.65 \cdot 10^{-24}$ gram). In terms of this unit, the mass of any atom is found to be nearly an integer, i. e., to differ from some integer by an amount very much less than unity: This nearest integer is called the "mass number" of the isotope. The mass

Written especially for ELECTRICAL ENGINEERING; based upon an address delivered before the communication group of the A.I.E.E. New York Section, New York, N. Y., April 23, 1935.

number A is affixed as a superscript to the chemical symbol of the element, so that $_1H^1$ (or simply H^1) denotes that isotope of hydrogen of which the atomic mass is nearly equal to 1, $_2He^4$ (or He^4) denotes that isotope of helium of which the atomic mass is nearly equal to 4, and so on.

I now give the list of the 20 lightest particles—not counting photons, and not counting certain unstable radioactive atoms such as the one denoted by $_7N^{13}$—which are at present known (see accompanying tabulation). All but the first 3 are nuclei of chemical atoms, and their masses are known with such accuracy that of the 4 significant figures which I shall quote, all are certain excepting that the fourth may in some cases be wrong by not more than one unit. (This is in fact a decided understatement of the accuracy of the best known values.) Actually the values standing in the table are not the masses of the nuclei, but those of the corresponding atoms: Since the atom is composed of the nucleus and Z negative electrons, the reader may deduce any nuclear mass by subtracting Z times the electronic mass from the given datum. The chief reason for citing so many nuclei more massive than the alpha particle is, that they take part in or spring forth from reactions of transmutation in which the lighter nuclei also are involved. As for the first 3 particles of the list, values of atomic number and of mass number have been assigned also to them, though this action requires a broadening of both concepts. The mass of the negative electron is 0.000548, the last significant figure being certainly not wrong by more than one unit. The masses of the positive electron and the neutron are going to be discussed in the course of this article.

The Deuteron—Nucleus of the Atom of Heavy Hydrogen

We now consider in succession the 5 newly discovered particles which appear among the 8 at the head of the list; and we begin with the "deuteron" (this name is proposed to supersede the earlier "deuton" and "diplon") which is the nucleus of the hydrogen atom of mass number 2, the second isotope of hydrogen which bears the name of "deuterium," is sometimes called "heavy hydrogen," and is sometimes denoted for convenience by the symbol D or $_1D^2$ instead of the natural $_1H^2$.

Heavy hydrogen, discovered in the autumn of 1931 and first reported to the world in the closing days of that year, proved itself so great an addition to the materials and the resources of chemist and of physicist alike (not to speak of the biologists) that in 3 years precisely it won for its discoverer the Nobel prize. It was not stumbled upon, it did not appear by some happy accident in the course of a research planned for other ends, as so often happens; it was deliberately sought after by Urey, who suspected it to be a scanty constituent of ordinary hydrogen, thought out a physicochemical method for concentrating it, applied the method with the aid of collaborators, and with them observed in the spectrum of the concentrated mixture a spectrum line distinctive of the new isotope. In ordinary hydrogen, there are more than 10,000 of the "light" atoms H^1 to every one of the heavy variety; yet by the spring of 1933, methods had been developed for concentrating the mixture—or, better expressed, for separating the heavy from the common isotope of hydrogen—so potent and efficient that samples of hydrogen, or of water or of other hydrogen compounds, in which the heavy atoms are more than a thousand times as abundant as the light ones, are frequently made and constantly used in laboratories. Indeed, it is asserted that samples of water have been made in which 99.99 per cent of the molecules are H^2H^2O instead of H^1H^1O, though there is now some doubt as to whether the criteria for estimating the relative amounts of the atoms H^1 and H^2 are as accurate as was thought. Such questions, however, do not affect us, and the voluminous knowledge of the chemical and physical properties of deuterium—already in 3 years and a half grown to the size of a small encyclopedia—does not concern us, so long as we are interesting ourselves in only the nucleus of the deuterium atom.

Table of the Lighter Elementary Particles

Arranged in order of increasing mass up to and including the 3 types of oxygen nuclei, and excluding certain unstable nuclei as well as corpuscles of light. The masses printed opposite nuclei are those of the corresponding atoms; the last significant figure quoted is almost certainly correct or at worst in error by not more than one unit

Atomic Number	Mass Number	Mass	Name
−1	0	0.000548	negative electron
+1	0	(cf. p. 815)	positive electron
0	1	1.008	neutron
1	1	1.008	proton
1	2	2.014	deuteron
1	3	3.016	H^3 nucleus
2	3	3.017	He^3 nucleus
2	4	4.003	alpha particle
3	6	6.016	Li^6 nucleus
3	7	7.017	Li^7 nucleus
4	9	9.014	Be^9 nucleus
5	10	10.01	B^{10} nucleus
5	11	11.01	B^{11} nucleus
6	12	12.00	C^{12} nucleus
6	13	13.01	C^{13} nucleus
7	14	14.01	N^{14} nucleus
7	15	15.01	N^{15} nucleus
8	16	16.00	O^{16} nucleus
8	17	17.00	O^{17} nucleus
8	18	18.01	O^{18} nucleus

Chemical symbols: H hydrogen, He helium, Li lithium, Be beryllium, B boron, C carbon, N nitrogen, O oxygen.

The Deuteron in Nuclear Chemistry; The Neutron

The charge of the deuteron is $+e$, since it is the nucleus of an atom which is an isotope of hydrogen. Its mass, determined as early as the spring of 1933, is 2.014. It plays a part in several very striking and important reactions of transmutation or of "nuclear chemistry," which I will presently describe, but not until after making some inferences from the mass and the charge of the deuteron.

The mass by itself would suggest that the deuteron is a pair of protons linked together. Such a combination however would not have the right charge; it must be completed by a negative electron—not, of course, an unwelcome supplement, since it might

supply the want of something to hold the protons together. Such a model was once the customary one, or at any rate would have been, had the deuteron been discovered sooner. Let us, however, make the hypothesis that the deuteron is made of a proton and a neutral particle, the latter of mass about equal to the difference (2.014 − 1.008) of deuteron mass and proton mass, about equal therefore to unity (the reader may expect me to say, *exactly* equal to the difference 1.006, but this would be wrong, for a reason later to be mentioned). Let us call this hypothetical particle the "neutron"; and let us inquire how the so-defined neutron might conceivably be observed.

First, it is conceivable that if a deuteron were to be projected with great energy against a massive obstacle—which would be, necessarily, a massive nucleus—it would break into a proton and a neutron, and the 2 would go separate ways. If a beam of fast deuterons were to be directed against a plate of, for example, lead, then protons and neutrons might be detected bounding back from the plate. Nothing of the sort has been observed, so far as I know, and so we will spend no more time over this possibility. It has, however, been observed that an impact of a deuteron against a corpuscle of light may lead to a separation of the 2 components; of this I will speak later.

Second, it is conceivable that if a deuteron were to be projected against another nucleus the neutron might stick to this nucleus, the proton go on by itself; and third, it is conceivable that in the same circumstances, the proton might stick and the neutron go on. Now, processes of both these kinds *have* been observed and can be produced at will. I describe some in detail.

Bombardment of Lithium by Deuterons Produces Heavy Lithium

A process of the second kind—the neutron sticking to the struck nucleus, the proton going on—would result in an elevation of the mass of the struck nucleus by about one unit, without any change in its charge. In other words, this process would transform the struck atom into an atom belonging to a different isotope of the original element, of mass number higher by unity than that of the original isotope. Here is an outstanding and thoroughly studied example. Lithium has 2 isotopes, Li^6 and Li^7 (their nuclei figure in our table), and after long labor it has been made possible to produce films of sufficient thickness (only a few atom layers are required) for the experiment, consisting almost exclusively of either isotope by itself. When a film of Li^6 is bombarded by a beam of fast moving deuterons, protons spring from the film: There is occurring the process,

$$_3Li^6 + {_1H^2} \longrightarrow {_3Li^7} + {_1H^1} \tag{1}$$

Deuterons are leaving their neutrons behind in the nuclei of the light isotope of lithium, which thus are becoming nuclei of the heavy isotope, while the protons originally attached to the neutrons go on by themselves.

If the arrow in equation 1 is replaced by the equals sign, we have what resembles an equation of ordinary chemistry, though it would have been unintelligible to the chemists of 25 years ago and incredible to those of 15 years ago: It is in fact an *equation of nuclear chemistry*. Considered as an algebraic equation, it balances in the atomic numbers (subscripts) and the mass number (superscripts). I shall be quoting several more, and yet they form only a minute fraction of the hundreds describing "nuclear reactions" which are already known.

One might expect to observe such a process whenever deuterons are used to bombard—as the term is—elements having 2 (or more) isotopes differing from one another by one unit in mass number. Additional instances of such elements in our table are boron, carbon, nitrogen, oxygen. Protons in fact are observed to spring from these elements whenever they are bombarded by energetic deuterons. It has not yet been possible to separate the isotopes of these elements so as to get "pure" films, and yet in the cases of carbon, nitrogen, and oxygen the lightest isotope is so greatly more abundant than the other or others, as to make it almost (not quite) safe to regard them for these purposes as consisting entirely of C^{12} and O^{16}. Another circumstance, later to be reviewed, stiffens the presumption that in all these cases the lightest isotope is being converted into the next lightest by absorbing neutrons from the bombarding deuterons: B^{10} into B^{11}, C^{12} into C^{13}, N^{14} into N^{15}, O^{16} into O^{17}. One of the most remarkable of these processes I postpone for the moment, and turn to the processes of the third kind, in which the proton sticks to the struck nucleus and the neutron goes onward.

Bombardment of Heavy Lithium by Deuterons Produces Helium

If the nucleus incorporates the proton into itself, both its mass number and its atomic number must ascend by one unit; it becomes not another isotope merely, but another element. We should be inclined to look for this to happen when adjoining elements (Z differing by one) have adjoining isotopes (A differing by one); boron of mass number 11 might readily—or so at least it seems—get transformed into carbon of mass number 12. As a matter of fact, neutrons have been observed emerging from boron bombarded by deuterons. But take a case like that of lithium, where the adjoining element ($_4Be$) has no adjoining isotope; if the heaviest nucleus of lithium ($_3Li^7$) were to absorb a proton, it would be converted into a nucleus which could be denoted only as $_4Be^8$, and it happens that in spite of very arduous and thorough searching, no isotope of beryllium of mass number 8 has ever been certainly proved to exist. Yet, the nucleus of the atom $_3Li^7$ can absorb a proton out of a deuteron, the neutron going on by itself; and what happens then, and in a number of similar cases, is very remarkable.

What happens in this particular case is described by the equation,

$$_3Li^7 + {_1H^2} \longrightarrow {_2He^4} + {_2He^4} + {_0n^1} \tag{2}$$

Two nuclei of helium spring from the scene of the transmutation! (As also does the escaping neutron, here denoted by a symbol implying that its charge is zero and its mass is nearly unity.) It is as if the lithium nucleus, having absorbed a proton out of the impinging deuteron, had then and there exploded into a pair of identical fragments. It would have been a Be^8 nucleus had it been able to hold itself together, but it could not; it was essentially unstable, as the absence of Be^8 from the chemistry of the earth suggests.

Is there actually a nucleus of Be^8 which is created and enjoys a brief existence before it explodes into the pair of helium nuclei? All that can be said is, that if such a one there be its lifetime is too short to have been detected up to now. A more satisfactory answer can be given in several cases, of which here is a much studied and fairly well known example: the reaction, or rather the pair of consecutive reactions,

$$_6C^{12} + {}_1H^2 \longrightarrow {}_7N^{13} + {}_0n^1 \tag{3a}$$

$$_7N^{13} \longrightarrow {}_6C^{13} + {}_1e^0 \tag{3b}$$

The deuteron impinges upon the carbon nucleus, which lets the neutron escape but captures the proton, and becomes thus a nitrogen nucleus of mass number 13—not, however, a stable nucleus, for on the one hand no isotope N^{13} of nitrogen has ever been detected in nature except under circumstances such as these, and on the other hand these particular nuclei are positively known to be unstable and to break down of themselves, because the nitrogen resulting from this transmutation is *radioactive*. The N^{13} nuclei mostly survive for an appreciable time before the breakdown; their lives are not all equal, but are distributed according to the law of chance about a mean value; the mean life is several minutes. The eventual breakdown is described by equation 3b, in which occurs a symbol standing for a particle of atomic number 1 and mass number 0, therefore of charge $+e$ and mass nearly zero. This is a "positive electron," one of the newly discovered elementary particles of our table; here I make only a casual reference to it, leaving it to be properly introduced later on.

Very Heavy Hydrogen and Light Helium

It would be justifiable to make a list of all the unstable nuclei discovered in such experiments—including very many produced by bombarding various atoms with protons, with alpha particles, and above all with neutrons—and add them to the list of the elementary particles; but this would take much too long, and indeed this article would practically never end if I were to let myself stray *ad libitum* among the wonders of transmutation. It will be wisest to conclude this part with the reactions which generate 2 more of the elementary particles of our table, the third and fourth lightest of all atom nuclei and the 2 lightest discovered by transmutation. Suppose *deuterons projected* with great force *against deuterons* (the target might be hydrogen gas or water or any other hydrogen compound containing a multitude of H^2 atoms). Conceivably there might be a process in which a proton went off free while its neutron stayed with the other deuteron; or conceivably there might be a process in which a neutron went off free, leaving its proton with the other deuteron. The new particle would consist of 2 neutrons and a proton in the one case, 2 protons and a neutron in the other. The processes occur and the particles are observed. Here are the equations:

$$_1H^2 + {}_1H^2 \longrightarrow {}_1H^3 + {}_1H^1 \tag{4}$$

$$_1H^2 + {}_1H^2 \longrightarrow {}_2He^3 + {}_0n^1 \tag{5}$$

The particles are denoted by self-explanatory symbols. The atoms of which they are the nuclei may well be styled "very heavy hydrogen" and "light helium," respectively. They share the mass number 3, but actually their masses differ by just a little, an amount on the verge of the detectable; the best estimates are 3.016 for $_1H^3$ and 3.017 for $_2He^3$.

Nothing as yet has been said here about the experiments from which all these so definite and confident statements are derived; and while an even partway adequate description of the methods would take an article of great length, they must not be entirely omitted.

Detection of Fast-Flying Charged Particles

Almost the whole of our knowledge of subatomic and elementary particles—including our knowledge of radioactivity, of transmutation, and of cosmic rays—is based on the fact that *we can detect fast-flying charged elementary particles through various of their effects, especially the ionization which they cause in traversing a gas.* For the sake of completeness I mention that these particles may be detected by the flashes which they set off when hitting a fluorescent screen, or the imprints which they make upon a photographic film. It is, however, their effect of ionizing a gas which is most often observed.

When a sufficiently fast-moving particle of any of the kinds appearing in our table (*the neutron alone excepted!*) is projected across a chamber full of air or any other gas, it ionizes the gas by detaching negative electrons from some of the molecules near or through which it passes, thus leaving along the path which it followed a trail of freed electrons and of positively charged molecules—the "ions." The number of ions, or rather ion-pairs (a pair being one liberated electron and the molecule from which it was liberated) per unit length of the path, in air of ordinary density, depends somewhat on the speed of the particle but chiefly upon its nature: An alpha particle will produce some 30,000 in a centimeter, an electron only a few score, while the other elementary particles have each their characteristic value of ionization per unit length of path or "density of track." The detachment of each electron or formation of each ion-pair costs energy, which is paid out of the kinetic energy of the fast-flying particle; hence the particle moves ever more and more slowly as it drives ahead, and if the gas is deep enough its traceable path comes rather suddenly to an end. The length of the path—which in air of ordinary density is called the "range"—depends on the nature

of the particle and on the kinetic energy which this had when it started into the gas, and may be used to tell the latter if the former is known. Also the energy may be learned by applying a magnetic field to the region which the particle is traversing, and measuring the curvature which the field imprints upon its path. The latter is the direct way, and serves for calibrating the other; very accurate measurements are made upon the kinetic energy of (say) alpha particles of various carefully measured ranges, and out of these an energy-versus-range curve is plotted which enables future observers to learn all they need about energies from simply observing ranges.

Of the various ways for detecting this ionization, the most spectacular is the wonderful scheme of the Wilson expansion chamber or cloud chamber, in which droplets of water large enough to be seen are condensed upon the individual ions, converting the hitherto invisible paths of the fast-flying particles into visible trails of mist. The term "mist" may suggest that the trails are hazy or vague, but actually under good conditions they are sharp and fine, as though a gleaming thin wire had suddenly been stretched taut across the chamber of gas. The length of such a trail from beginning to end may be measured quite closely. A mere inspection of the trail often suffices to show to the practiced eye what the nature of the particle was; if not, this may be learned by repeating the experiment with some electrometric device which measures the total charge of all the electrons liberated along the path, therefore the total number and the number per unit length of path of the ions which the particle formed as it flew along. These observations jointly establish what the nature and the energy of the particle were. In such a way as this, the protons figuring on the right-hand side of equation 1 and the alpha particles on the right-hand side of equation 2 and the newly discovered particles on the right-hand sides of equations 4 and 5 were detected and were identified.

Not so, however, for the neutrons! The quality of being able to leave behind a trail of ions in a gas is confined to elementary particles which are *charged*. Positive corpuscles attract the negative electrons of the molecules near or through which they pass, negative corpuscles repel them; in either case it happens, with an oftenness indicated by the figures which I gave before, that the interaction results in a total expulsion of the electron from the molecular structure which was its home. Neutrons exert neither the one kind of force nor the other, and fly through meters of air without ever setting a single electron free. Not only the Wilson cloud chamber, but all the other methods for detecting the passage of a charged elementary particle, are completely futile.

How the Neutron Was Discovered

A totally uncharged particle of subatomic size is indeed a strangely evasive and surreptitious being; it has no optical, no electrical, no photographic effects; and neutrons would still in all probability be quite unknown as independent particles, were it not that when a stream of them is pouring through a solid or across a gas, a very few of them will strike so squarely against the nuclei of a very few atoms, that these nuclei take over a large share of their kinetic energy in an elastic recoil, and voyage onward themselves as fast-flying *charged* particles capable of producing all the effects of which I have been speaking. This occurs particularly well in hydrogen, for H^1 nuclei or protons have very nearly the same mass as a neutron, and by a well-known theorem of mechanics the exchange of energy between 2 elastic colliding particles is greatest when their masses are equal. Indeed, a perfectly central impact of a neutron against a proton entails the total transfer of the kinetic energy of the former to the latter, if the impact is perfectly central: One has thus only to select the proton-paths which are directed straight away from the neutron source, estimate from them the energy of the protons and identify it with that of the neutrons. The experiment may be performed by admitting the neutrons to a Wilson chamber containing hydrogen instead of air; best of all is to send them through a windowpane made of paraffin or some other solid material rich in hydrogen, for then they have ample opportunities to make such collisions, and great numbers of protons will leap out of the paraffin.

In this manner the neutron was discovered. The source, or what was later to be recognized as the source, was set close to an ionization chamber, i. e., a thin walled capsule filled with gas and equipped with a device for detecting and measuring the ionization in the gas; and it was observed that when a sheet of paraffin was slipped between the chamber and the source, the amount of the ionization in the chamber increased immensely. This observation was made by Joliot and Madame Curie-Joliot; the mysterious rays had earlier been detected by Bothe and Becker who had interpreted them as gamma rays—which is to say, as high frequency light—and this interpretation lingered on even after the Joliots had discerned the effect of paraffin, until it was supplanted with the proper one by Chadwick. The honor of discovering the neutron is thus to be divided among 3 nations and 5 physicists. Incidentally, the source in these experiments was a piece of beryllium which was being bombarded by alpha particles, in which consequently the following process was going on:

$$ {}_4Be^9 + {}_2He^4 \longrightarrow {}_6C^{12} + {}_0n^1 \qquad (6)$$

This was the first to be discovered of the nuclear reactions generating free neutrons, and is still ranked among the most prolific.

Nuclear Mass and Kinetic Energy

Something must now be said about mass and kinetic energy, since these 2 are closely interrelated in a way which confirms Einstein's great principle of the equivalence of mass and energy, which enables us to evaluate nuclear masses with a precision exceeding the 4 significant figures which are all that I am quoting, and which serves as a good preparation for what I shall say about the positive electron.

To introduce this subject I bring out the last of the reactions involving the neutron which is to appear in this article:

$$\phi + {}_1H^2 \longrightarrow {}_1H^1 + {}_0n^1 \tag{7}$$

Here ϕ stands for a photon or corpuscle of light. The reaction occurs when deuterium is bombarded, or irradiated, with light of extremely high frequency—gamma radiation from radioactive bodies. Under these circumstances, Chadwick and Goldhaber have found that protons spring from the deuterium. The deuterons or H^2 nuclei are dissociated by the gamma rays. As I said before, we cannot (as yet) affirm that the deuteron can be broken apart by hammering it against a hard material wall; but we may affirm that it *can* be broken in 2 by hammering it with a corpuscle of light.

We now attempt to convert equation 7 into an actual equation for the masses. The first problem arising is, what mass to assign to the photon? One is not accustomed to speaking of the mass of a corpuscle of light; but the energy of such a corpuscle is well known—it is $h\nu$, where ν stands for the frequency of the light (which is ascertainable) and h for a known fundamental constant of Nature, Planck's constant. Now according to Einstein's principle already mentioned, energy E is always linked with mass E/c^2; here ν stands for another fundamental constant of Nature, the speed of light in vacuo. We therefore set $h\nu/c^2$ for the first term of our equation. Next come the masses of the nuclei ${}_1H^2$ and ${}_1H^1$. One would naturally take them from such a table as appears in this article; but *all the values given in such a table refer to particles at rest or moving relatively slowly, whereas the particles resulting from a reaction of transmutation are often shot off with enormous speeds!* The reason why this matters is, that according to the relativity theory and to experiment alike, the mass of a material particle increases with its speed. It is the augmented mass of the high speed nucleus, not the lesser mass of the same nucleus while at rest, which ought to be put for (say) ${}_1H^1$ in our equation. Another way of saying the same thing is, that whenever a nucleus or any other material body is in motion, it is carrying not only its rest mass but also the mass of its kinetic energy; denoting by T this energy, we have T/c^2 for the extra mass. Taking into account these extra masses of the newborn proton and neutron, but disregarding that of the deuteron on the ground that this particle is nearly standing still (its speed of thermal agitation being inconsiderable from this viewpoint) when the photon strikes it, we write the following equation of masses:

$$h\nu/c^2 + {}_1H^2 = {}_1H^1 + {}_0n^1 + T_H/c^2 + T_n/c^2 \tag{8}$$

where now the symbols for the various nuclei stand definitely for the rest masses taken from the table, while T_H and T_n stand for the kinetic energies of proton and neutron, respectively. T_H is ascertainable, because the protons resulting from the reaction have a measurable range; T_n may be set equal to T_H, because we know that the masses of proton and neutron are almost the same, and therefore the momenta and therefore the kinetic energies with which they spring apart must be nearly the same in order to conform with the principle of the conservation of momentum.

If all the masses appearing in equation 8 were known with sufficient accuracy, we could use the equation to test Einstein's principle. Actually, all of them are known with sufficient accuracy, excepting the term ${}_0n^1$; it is therefore customary to *solve equation 8 for the rest mass of the neutron,* taking Einstein's principle for granted. The value thus obtained, quoted to 4 significant figures is 1.008—the same to 1 part in 1,000 as the mass of the proton.

To test Einstein's principle it is necessary to use some nuclear reaction in which all the rest masses are known with sufficient accuracy and all the kinetic energies are measurable. Two excellent examples are the following:

$$ {}_1H^1 + {}_3Li^7 \longrightarrow {}_2He^4 + {}_2He^4 \tag{9}$$

$$ {}_1H^2 + {}_3Li^6 \longrightarrow {}_2He^4 + {}_2He^4 \tag{10}$$

These reactions resemble equation 2, but are not identical with it: In one case a light hydrogen nucleus is captured by a heavy lithium nucleus; in the other case a heavy hydrogen nucleus is captured by a light lithium nucleus; and in both cases we obtain not a single consolidated particle (which would be a nucleus of ${}_4Be^8$) but a pair of identical fragments flying off in opposite or nearly opposite directions.

If now we treat expressions 9 and 10 as equations, and replace the symbol of each nucleus by the corresponding rest mass, we meet trouble at once: The left-hand member of expression 9 is equal to 8.023, the left-hand member of expression 10 to 8.028, and the right-hand members of both are equal to 8.004. (Note that these figures, being derived from the table, include in each case the mass of 4 electrons, which cancels out.) The unbalances are far in excess of the limit of possible error. They are, however, converted into excellent balances, when the extra masses due to the kinetic energies of the helium nuclei (those of the particles on the left-hand sides of the equations are negligibly small) are inserted on the right. There are other such cases which fortify Einstein's principle, and still others (the reaction 2 is one of these) which supply additional estimates of the neutron mass when the principle is accepted; while several of the mass values appearing in our table—those of ${}_1H^3$ and ${}_2H^3$ among them—are obtained by applying the principle to reactions of transmutation from which the particles in question spring.

Binding Energy an Index of Stability

Some readers perhaps may recall that originally I defined the "neutron" as a hypothetical neutral particle existing in combination with a proton to form a deuteron; that the difference between the masses of deuteron and proton (which are 2.014 and 1.008, respectively) is 1.006; and that the mass of the newly discovered free particle called by the name of neutron is not 1.006 but 1.008. This discrepancy is not unwelcome, but the contrary. Let

us suppose that the neutron and the proton attract one another strongly when they are very close together—as indeed they must, for otherwise the deuteron could not exist. Energy will then be required to pull them apart: When a photon effects the reaction expressed in equation 7, part of its energy must be used for this purpose, and only the remainder will become kinetic energy of neutron and proton. In other language, out of the initial energy $h\nu$ of the photon, a portion B is spent in "breaking the bond" between the constituent parts of the deuteron, the remainder $(h\nu - B)$ in giving to these the kinetic energies T_H and T_n. We may apply the name of "binding energy" to B. Remembering that energy has mass, and referring back to equation 8, we learn:

$$({}_1H^2 - {}_1H^1) + B = {}_0n^1 \tag{11}$$

The rest mass of the free neutron exceeds the difference between the rest masses of deuteron and proton by an amount which is the binding energy of the deuteron. The whole (the deuteron) seems to be smaller than the sum of its parts (proton and neutron)! This however is not so, for we have to add something (*viz.*, the binding energy) to the "whole" in order to get the parts. Reversely, if the "whole" is made by bringing the parts together, the binding energy must be released and take its departure; we may imagine it as going away in the form of a photon of energy B and mass B/c^2, though there are other possibilities.

The difference 0.002 between the masses 1.006 and 1.008 is therefore nothing to be worried about; on the contrary, it is a measure of the energy which must be imparted to the deuteron in order to dissociate it, and thus an indication of the *stability* of the deuteron. Such estimates of stability are made whenever the data permit. Thus if we suppose the alpha particle to be made up of 2 protons and 2 neutrons, the sum of the rest masses of its presumed constituents is greater by 0.030 than the rest mass of the particle itself; this is a tremendous difference as such things go, and amply sufficient to explain why no one has succeeded in breaking up the alpha particle by bombarding it with photons, for no photons of anywhere nearly so great an energy can be generated by any apparatus yet developed. The corresponding argument applied to ${}_1H^3$ and ${}_2He^3$ gives much smaller margins of stability, and yet they are greater than the margin for the deuteron.

As I have just been implying without actually saying, the present day custom is to suppose every nucleus to consist of protons and neutrons in sufficient number to account for the actual atomic number and mass number of that nucleus: to wit, Z protons and $(A - Z)$ neutrons. This idea was actually suggested a number of years ago, but never met with general acceptance until the neutron was discovered "on the loose," so to speak, as a free particle freely wandering in space. Till then it was the custom to suppose each nucleus to consist of A protons and $(A - Z)$ negative electrons. One cannot say, however, that this idea is extinct, for in the first place there are certain radioactive nuclei which eject negative electrons, and in the second place there is a great desire to interpret the neutron as a combination of a proton and a negative electron. On the other hand there are also radioactive nuclei which eject positive electrons (I have already given an example in equation 3*b*) and there is a desire to interpret the proton as a combination of a neutron and a negative electron. It is clear at all events that we might reduce the 4 lightest elementary particles of the table to 3 "ultimates," if we could prove either that the proton is a neutron plus a positive electron, or that the neutron is a proton plus a negative electron. Now, the argument about stability seems to offer at least a partial test: If the rest mass of the proton were inferior to the sum of the rest masses of neutron and electron, this would speak in favor of the first alternative; if the rest mass of the neutron were inferior to the sum of the rest masses of proton and electron, it would speak in favor of the second. But the rest masses of proton and neutron seem to be equal as far as the fourth significant figure, and the immediate question at issue cannot be resolved without certain knowledge of the fifth, so that it is as yet an unsettled question.

"Spin" of the Nucleus an Important Feature

Reverting, for a paragraph, to the nuclei which are known to be composite, and in particular to those of our table which are the simplest known structures: The values of their binding energies are among the most important of their characteristics, and one of those on which we must rely for guidance and test in contriving the theory of these constructions. Another important feature is the "spin" or angular momentum of the nucleus, for protons, deuterons, and most other nuclei, as well as electrons, are *whirling* bodies. There is a unit of nuclear spin, as inconceivably small by comparison with the angular momenta of ordinary wheels as are nuclear masses by comparison with the masses of ordinary tangible objects. The spin of the proton amounts to one of these units, the spin of the deuteron to 2; we infer that the spin of the neutron (which unluckily is inaccessible to measurement) is also one unit, and that neutron and proton set themselves end to end with their spins pointing in the same direction and compounding themselves into a single spin of double value. (This statement requires a minor modification to be in harmony with quantum mechanics, but we need not enter so far into detail.) The spin of the alpha particle is zero, as if the protons and the neutrons set themselves end to end with their spins opposing and therefore counteracting one another; so are those of the nuclei ${}_6C^{12}$ and ${}_8O^{16}$. The spins of the nuclei ${}_3Li^7$ and ${}_7N^{14}$ are 3 and 2 of these units, respectively. These items also must be explained by any competent theory of the way in which nuclei are constructed, and it can only be hoped that the severity of the requirements which they set will be matched by the value of the hints which they give. It is unfortunately to be added that the spins of the other nuclei figuring in our table are not known (though those of many yet heavier nuclei have been ascertained) and some perhaps never will be.

The Positive Electron

The positive electron has already made its entrance into this article by way of the transmutation described by equation 3*b*. There is, however, a much simpler and more startling way of bringing it into being, than that or any other process which involves a nucleus. This is one of the primordial processes. Its equation is as follows:

$$\phi \longrightarrow {}_{-1}e + {}_{+1}e \tag{12}$$

A corpuscle of light transmutes itself into a pair of electrons, one negative, the other positive.

Incredible as this reaction seems to any physicist who has been reared in the belief of the permanence and the immutability of electricity, it conforms with all the major principles of conservation but one, and with this one it may be made to conform by a plausible addition. Conservation of *net* charge is sustained because equal and opposite charges are created: The addition of $+e$ and $-e$ to the electrification of the universe makes no alteration on balance. As to conservation of mass: Rewrite equation 12 as an equation of masses,

$$h\nu/c^2 = {}_{-1}e + {}_{+1}e + T/c^2 \tag{13}$$

where T stands for the sum of the kinetic energies of the 2 newborn electrons. It is then evident that the law of the conservation of mass will be maintained, if T is found by experiment to be equal to the difference between the energy of the photon and the energy equivalent of twice the rest mass of an electron. Experiment does yield this result, so far as the conditions permit: which is to say that when sheets of matter are bombarded by gamma radiation, pairs of electrons of opposite sign are occasionally observed to spring from a single point, and the sum of their kinetic energies may attain but never exceeds the difference between the energy $h\nu$ of a gamma ray photon and the energy equivalent of the doubled rest mass of an electron. (It often falls below, but this is readily explicable on the ground that most of the electrons lose a good deal of their energy in escaping from the solid sheet of matter into the gas where they first become observable.) Conservation of mass is therefore verified, and so, automatically, is conservation of energy. There remains the conservation of momentum, and this at first glance makes the situation serious, for the process described in equation 12 is one in which the momenta of the resultant particles cannot possibly equal that of the photon. It is, however, a fact that the creation of electron pairs out of light has never been observed in empty space, but only in the midst of matter, and especially of massive atoms; when diverse substances are irradiated by gamma rays, the process happens oftenest in lead, much more seldom in aluminium or carbon, while in gases only a few examples have been seen. We may now assume that the transmutation depicted in equation 12 occurs only in the immediate vicinity of an atom nucleus, and that this nucleus, without itself undergoing any change, is set into motion with just enough momentum to balance the momentum budget. Of course it must also possess some kinetic energy likewise derived from the photon, which strictly should be entered on the right of equation 13; but the amount of this turns out to be negligibly small by comparison with the other terms already entered there. The idea may seem somewhat artificial, but it is fully borne out by the successfulness of the quantum mechanical theory of the process. Charge and mass and energy and momentum are therefore all preserved intact when photons are converted into electrons, and no violence is done to anything excepting our inbred idea that electricity and light are somehow different and noninterchangeable in nature, which we are now obliged to abandon.

Positive Electrons Produced in Several Ways

I have acquainted the reader with 2 ways in which positive electrons are produced; there are yet others. Every now and then, in the solid objects which surround us here on the surface of the earth, and probably in the atmosphere as well, there occur terrific atomic explosions in which dozens, scores, or even hundreds of charged particles are fired in all directions. Many if not all of these particles are electrons; some are negative, and some are positive. It is presumed that these explosions are provoked by photons of colossal energy falling upon the earth from outer space, but this is a question into which I should not enter here. The electrons may be created in pairs out of the energy of the photon, but this cannot at present be proved. Occasionally one sees (in the Wilson chamber) the tracks of a single electron pair, and it seems almost indubitable that such a one must have been produced by the process of equation 12. Occasionally one sees the tracks of an electron pair leaping out of a lead plate just where an immensely fast electron has shot through the plate, and theory confirms the inference that the 2 new electrons have been created out of a portion of the kinetic energy of the old one. The very first positive electron ever recognized was wandering by itself inside a Wilson chamber in Pasadena, Calif., when C. D. Anderson by a happy chance condensed the water vapor on its track and so obtained a photograph thereof. All these, I hardly need say, are phenomena of the cosmic rays.

(It may have been noticed that I have assumed throughout that the mass and charge of the positive electron are equal in magnitude to those of its negative counterpart. This expresses our faith, rather than the result of accurate experiments. Measurements on the mass, or rather upon the charge-to-mass ratio, of the positive electron have already been commenced, but as yet they fall far short of the accuracy attained with the negative electron. They make it certain, however, that this ratio has the same value within a few per cent in both cases.)

Turning the arrow around in equation 12, we find ourselves confronted with the description, or rather the partial description of the converse process: 2 electrons meet and are converted together into light. If they become a single photon, conservation of momentum requires as before that the nucleus of some atom should participate in the process to the extent of taking some momentum and

a small quantity of energy, and this energy should strictly figure in the equation corresponding to equation 13 but may be disregarded so long as we remember that properly it should be there. (It is conceivable also that the 2 electrons might be converted into 2 photons sharing the available energy, and in such a case the participation of a nucleus is not required.) Now it is actually observed that when a stream of positive electrons is projected into a stratum of dense matter, photons of high energy shoot forth. Something of the sort is indeed observed when the infalling electrons are negative; but the positives produce a greater number of photons, and these extra ones have just the energy which equation 13 suggests. One would expect the positive electron to be more likely to unite with a negative electron after it has come nearly to rest than while it is still plunging forward at high speed into the stratum; in this case there would be little kinetic energy figuring on the right of the equation, and the energy of the newborn photon would be about the same as twice the rest mass of an electron. Well, this *is* a feature of the extra radiation stimulated by positive electrons driving into matter, as nearly as the very difficult experiments can tell. It appears that the positives retain their identity while they retain their high speed, but either they never come down to the relatively low speeds characteristic of the "conduction" electrons roving through the matter (if it be a conductor) and the "bound electrons" attached to the atoms, or if they do slow down to these speeds it is not for long: Each presently meets with a negative in such a fashion that the encounter is fatal to them both.

It seems as though in speaking of the positive electron I had for the first time introduced a mortal particle, in contradistinction to the presumptively immortal atom nuclei and negative electrons of the remainder of the list. The negative electron is, however, no less mortal than the positive, inasmuch as the 2 of them vanish together into light; and so far as the atom nuclei are concerned, if any one of them should ever meet a particle identical with it except in sign, the presumption is that the 2 could effect just such a merger as electrons can. It happens however that the electron is as yet the only particle of which there are known to be 2 varieties, antagonistic in sign and apparently alike in every other way. If either kind of electron were altogether missing we should suppose the other to be immortal, as we so long supposed the negative to be; if both were equally common the world would be unlivable, the interchange of substance between the form of electricity and the form of light being so abundant and incessant; it is because one kind is so very much rarer than the other and yet not entirely absent, that it is obviously ephemeral while the other gives the impression of durability..

Practical Applications of Insulation Research

By
D. W. ROPER
FELLOW A.I.E.E.

Commonwealth Edison Co., Chicago, Ill.

By applying the results of insulation research to factory equipment and procedures, manufacturers of oil-impregnated paper-insulated cables for electric power transmission and distribution have been able to effect marked improvements in their products. By following and taking advantage of these improvements as they develop, users of cable have been able not only to obtain more satisfactory operating results, but also to effect substantial savings. Some of the more recent achievements in insulation research and their practical applications are outlined briefly in this paper.

IN a previous paper[1] the author gave some test data and conclusions derived from accelerated aging tests of 69 kv cables. Those tests consisted of the application of from 1.5 to 3 times normal voltage and daily load cycles reaching a maximum of 84 cycles. As was shown in figure 9 of that paper, the lead sheaths of the cable samples were insulated from ground and from each other. Test leads were provided so that the sheath of each section of cable could be connected separately through a Schering bridge apparatus to ground. Measurements then were made on the insulation in that one section. Changes in the cable with age in these tests were determined at intervals by power factor measurements and by examinations of the insulation before and after the test.

A new series of accelerated aging tests on 19 samples of 69-kv single-conductor cable is now in progress at the high voltage laboratory of the Commonwealth Edison Company, Chicago, Ill. The

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1. For all numbered references see list at end of paper.

cables set up ready for test are shown in figure 1. All methods of testing and examining the insulation followed in the previous tests will be utilized, and, in addition, use will be made of several new tests that have been devised in the meantime.

Radial Power Factor Tests

One of the most interesting of the new tests is the radial power factor test of impregnated paper insulation described by Wyatt, Spring, and Fellows.[2] In this test, power factor measurements are made on the impregnated paper tapes, one at a time, and the results are shown graphically for a radial path through the insulation. During the past year in which results of the tests from similar apparatus in the laboratories of the Commonwealth Edison Company have been available, several such radial power factor tests have been made, not only on the 69 kv cable included in the present accelerated aging tests, but also on several other cables. By comparisons and analyses of the results of the tests, some familiarity with this new tool has been developed so that it can be used to advantage in connection with the accelerated aging tests.

Figures 2 and 3 show the results of the radial power factor tests on most of the samples included in the present accelerated aging test. The results of these tests appear to show a sufficiently wide range in the value of the power factor and in the shape of the curves to make it possible to determine the importance of these factors on the quality of the insulation. Some of these curves have the shape of an unsymmetrical letter "U," that is, they show marked upturns near the conductor and the sheath. Several of the curves show some irregular variations from the U shape, the causes of which are not immediately apparent but might become apparent through consideration of other information.

The cable from which curve *B* in figure 3 was obtained included several different grades of paper. Such radial power factor curves should be helpful to the manufacturer in determining the most suitable grade for the purpose.

Figure 4 shows that a material improvement has been made in the radial power factor curves for cable made in one factory during a period of several years. Similar improvement has been made by other manufacturers. However, no single curve combines the 2 most desirable qualities, namely, a low power factor

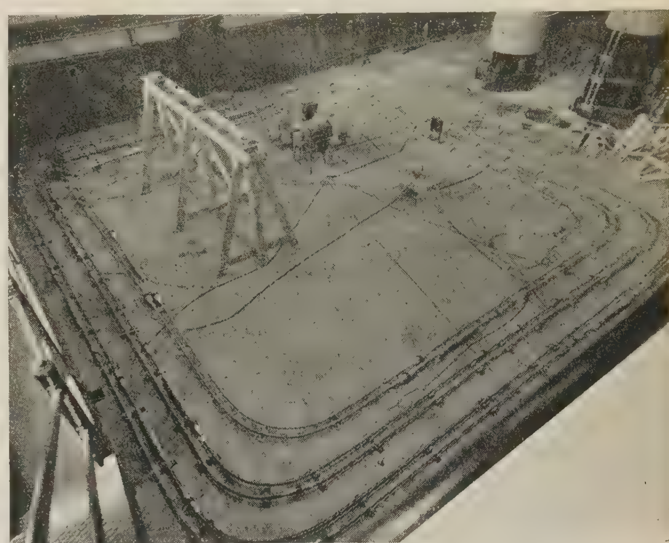


Fig. 1 (above). Interior of laboratory with 19 samples of 66-kv cable ready for aging tests

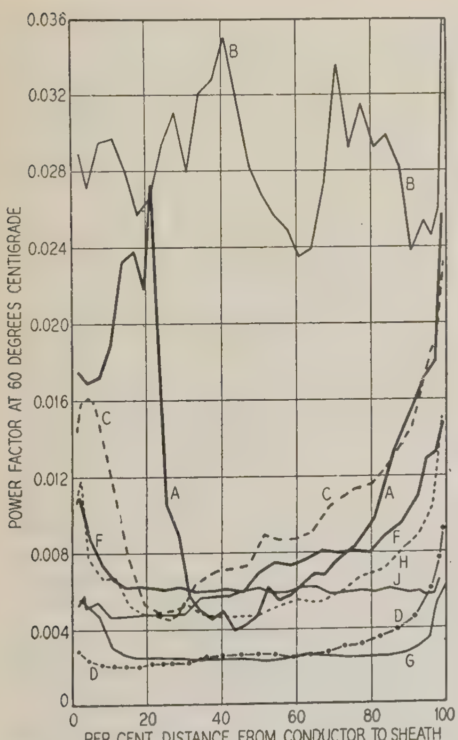


Fig. 2. Radial power factor of new 69-kv single-conductor cable of different makes

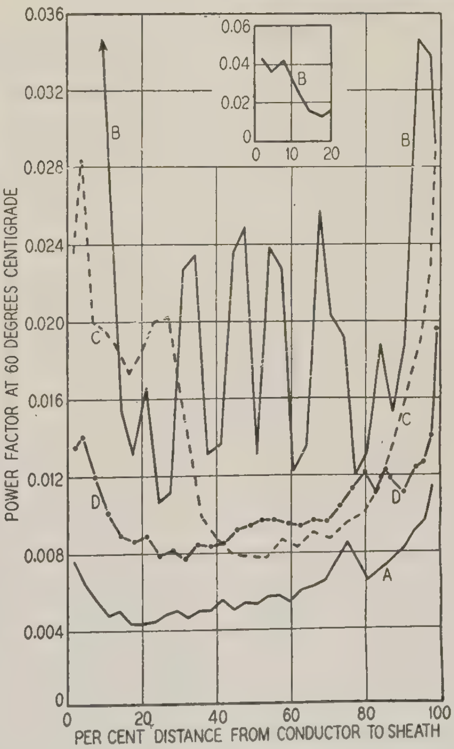


Fig. 3. Radial power factor of used 69-kv single-conductor cable of different makes

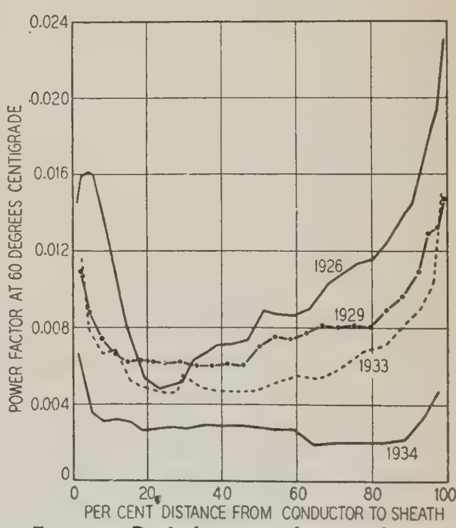


Fig. 4. Radial power factor of new 69-kv cable of make C showing marked improvement achieved between years 1926 and 1934

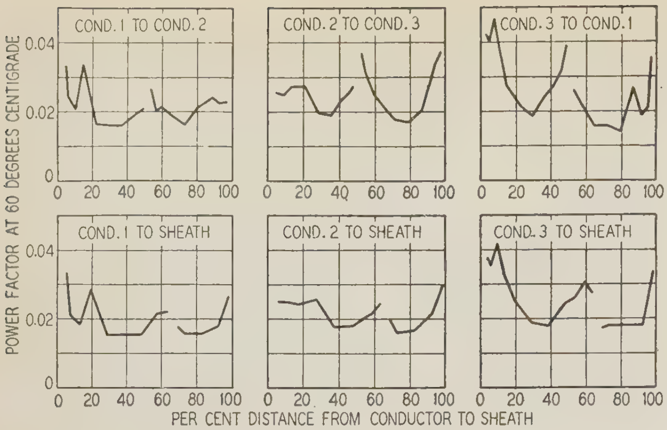


Fig. 5. Radial power factor of used 13-kv 3-conductor cable of make B

and a horizontal straight line without upturns near the conductor and sheath. One manufacturer has explained that the slight upturn next to the sheath resulted from the use of manila paper for the outer layer of paper tapes; but this explanation covers only 1 or 2 tapes, while the upturns in the curves usually involve many tapes.

The apparatus used for measuring radial power factor has electrodes $^1/_2$ inch in diameter and is arranged so that these electrodes are used also as a micrometer. Accordingly, measurements of the thickness of each tape as well as the power factor are included in the reports. For one cable it was noted that 3 thicknesses of tape were used, nominally 5, 6, and 8 mils, and, disregarding the upturns near the conductor and sheath, that the power factor of the tapes improved as the thickness increased. The thinner tapes appeared to be more dense than the thicker ones, which might account for the higher power factors.

In one instance, tests were made on 2 samples from the same piece of cable 140 feet apart. With allowance for errors in observation and the variations in commercial paper, the 2 curves were identical. While enough tests of this kind have not been made to warrant a final conclusion, it appears that in high grade cable made by a modern process the insulation is of uniform quality throughout the length of a section of cable.

Radial power factor tests on 3 conductor cable show curves (figure 5) similar to those for single conductor cable, the principal difference in the most recently made cable being in the value of the power factor; that is, the minimum power factor obtained from a 3 conductor cable is from 10 to 75 per cent higher than the minimum power factor obtained from a 69-kv single-conductor cable. There are some indications that this difference is attributable to the same cause as the upturn next to the conductor and the sheath in the samples made by certain factories, that is, to the contaminants that accumulate on the bare conductor and on the outer layers of an insulated conductor during the interval between manufacturing operations. This point was brought to the attention of one manufacturer, and radial power factor tests were made before and after the manufacturer made some slight changes in his equipment and/or processes in the factory. The results of these tests showed that the upturns in the curves near the conductor and sheath were eliminated by the manufacturer's changes, except for the slight upturn resulting from the use of manila paper for the outer layer. The elimination of the upturns in power factor near the conductor and near the sheath thus is shown to be entirely within the control of the manufacturer. Radial power factor curves for cables manufactured after such changes had been made

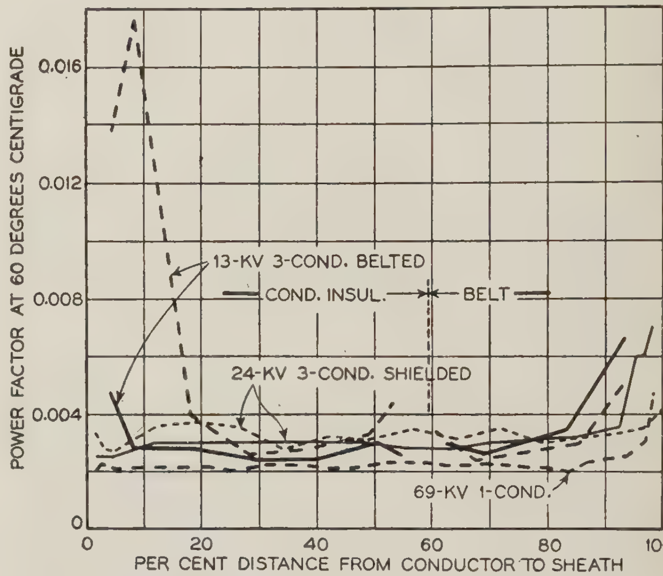


Fig. 6. Radial power factor of new cable made in 1934 by one manufacturer

are shown in figure 6. It may be noted that there is very little difference in the minimum power factors of 3 conductor belted cable, 3 conductor cable with shielded conductors, and 69-kv single-conductor cable, except in the insulation near one of the 3 conductors of one sample. The limited information available indicates that this one sample of 3 conductor cable with an outer belt of insulation was not typical of the best practice of this factory.

A further indication that the insulation acquires contaminating substances during intervals between operations in the factory is obtained from a sample of 69-kv single-conductor cable. The radial power factor curve of the insulation of this cable when new, as shown in figure 7, has a slight, almost insignificant, hump about 40 per cent of the distance from conductor to sheath. On first glance, one might think that this hump resulted from an error in observation or some other trivial cause; but after the cable has been subjected to an accelerated aging test, an entirely different idea is obtained. This cable was made in a factory where, because of limitations of the taping machine, the paper tapes had to be applied in 2 operations. It is quite evident from the curve that all of the thinner tapes were applied in one operation and all of the thicker tapes were applied in the second operation. During the interval between the 2 operations, the partly insulated conductor

stood on reels in the room where the taping machines are located.

Apparently the upturn in power factor near the conductor is attributable either to fine solid particles of dust and condensed vapors deposited on the conductor while standing around the factory before the paper tapes were applied or to copper soaps

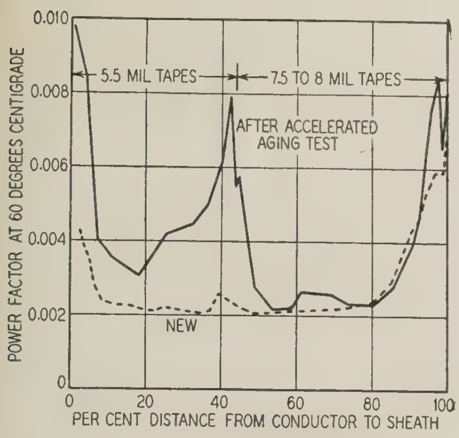


Fig. 7. Radial power factor of 69-kv cable made in 1931 before and after aging test

Peaks near the middle of the curves show the result of applying the paper tape to the conductor in 2 operations

formed by chemical action with the oil. The upturn at the 40 per cent point is attributable to the solid particles collecting on the outer layers of paper of the partly insulated conductor, and perhaps also to vapors absorbed by these outer layers of paper, while standing in the factory before the remaining paper tapes were applied. The upturn in the curve of new cable next to the sheath probably is ascribable, in part, to the same causes and, in part, to oxidation

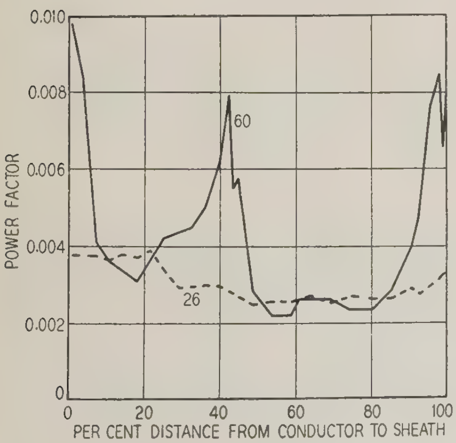


Fig. 8. Comparison of radial power factor at 26 and 60 degrees centigrade of 69-kv cable made in 1931

of the oil as it is exposed in the factory after the removal of the cable from the impregnating tank and before application of the lead sheath.

This cable was of excellent quality, as shown by the accelerated aging test. Even at the summit of the peak near the center of the insulation, the power factor is not much higher than that of the product of some other factories when new; but the curve, taken in connection with other curves, indicates that more careful "housekeeping" in some of the factories would be of assistance in producing impregnated paper insulation of the highest quality. Information obtained from the radial power factor tests has been found by cable manufacturers to be so interesting that several of them have equipped their laboratories with apparatus for making such tests.

In figure 8 the curves of power factor at 26 degrees centigrade and at 60 degrees centigrade for the 69 kv cable that has been subjected to an accelerated aging test show that comparatively little information is obtained from tests at the lower temperature and that the curves obtained at 60 degrees are far more informative and useful.

Breakdown Voltage Tests

A further point regarding the present status of research on impregnated paper insulation becomes more apparent by first considering briefly the improvements in impregnated paper insulation in the past 15 years.

In 1919 the Commonwealth Edison Company prepared specifications for 3 conductor cable to be operated at 12 kv which required breakdown voltage tests on short samples, and this requirement was included in specifications issued by the National Electric Light Association in the following year. In 1924 the Association of Edison Illuminating Companies prepared cable specifications, mainly for high voltage cable with some new requirements. Based largely upon a series of life tests made by the Commonwealth Edison Company, these specifications required much higher short-time breakdown strengths and a long-time test. These and subsequent changes in cable specifications are shown graphically in figure 9.

Breakdown strengths of 3 conductor cable for operation at 12 kv are shown in figure 10. For simplicity, the data are for one make of cable furnished to the Commonwealth Edison Company, but these results are quite typical of improvements made by practically all American manufacturers in this period. The short-time breakdown strength has increased by more than 200 per cent although during the same period the insulation thickness has been

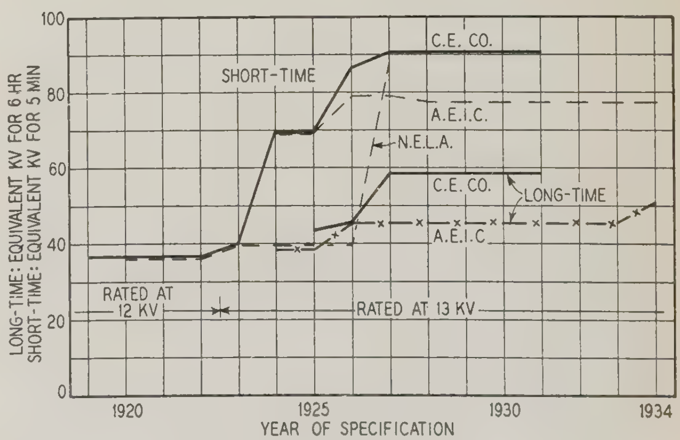


Fig. 9. Required breakdown strengths of 3-conductor cable for 12-kv operation

Equivalent voltages were determined by use of the relation between voltage and time given by F. M. Farmer[3]

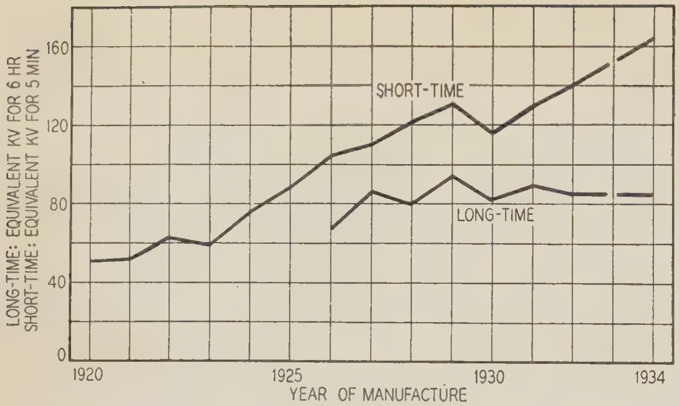


Fig. 10. Breakdown strengths of 13-kv 3-conductor cable on short- and long-time tests, depicting the steady improvement of the insulation

Equivalent voltages were determined by use of the relation between voltage and time given by F. M. Farmer[3]

reduced about 25 per cent. With due allowance for this difference in thickness of insulation, the present-day insulation will withstand a high voltage test about 4.4 times as severe as the same thickness of insulation would withstand in 1920. The service record shown in figure 11, of the 13-kv 3-conductor cable made in 1924 shows only one burnout resulting from defective insulation per 300 miles of cable per year, a very satisfactory service record. The breakdown strength of this cable for 5 minutes' duration was 6 times normal operating voltage. Since 1924 this figure has increased to 12 times normal operating voltage, as indicated in figure 10, showing that so far as this property of the insulation is concerned a considerable reduction in the present thickness of insulation, which is the same as that used in 1924, would be warranted.

Dielectric Loss

Dielectric loss was a troublesome factor in the earlier days and was the cause of many hundreds of cable failures in the United States. Bang and Louis[4] showed the importance of this factor in a paper presented to the A.I.E.E. in 1916. Rayner[5] of the National Physical Laboratory presented a paper to the Institution of Electrical Engineers, London, in 1912, in which he announced for the first time a wattmeter for measuring the power factor of the dielectric loss, but the first measurement of this kind reported in the technical laboratories of the United States was reported by Clark and Shanklin[6] in their paper presented to the A.I.E.E. in 1917. Figure 12 shows how rapidly American manufacturers reduced the dielectric loss of impregnated paper insulation after their customers learned how to measure this property of the insulation.

These improvements in paper insulated cable have produced marked economies. Table I shows, for example, a comparison between the cost of 500,000-circular mil 3-conductor cable for operation at 12 kv of the quality made in 1920 with that made recently. If such cable of the quality furnished in 1920 were used now, the cost per kilovolt-ampere of capacity would be about 27 per cent higher than the present cost.

The lower allowable operating temperature for the old cable was necessitated largely by the high loss in the insulation which is shown in figure 12 in terms of power factor. If the 1918 standardization rules of the A.I.E.E. were in use today, the maximum allowable operating temperature for 69 kv cable would be 45 degrees centigrade instead of the present value of 60 degrees. Furthermore, if the dielectric losses in such cable were as high as those of the 12 kv cable made in 1920, the 69 kv cable would be heated to its maximum allowable operating temperature when carrying no load. In other words with insulation of the quality produced in 1920, use of 69 kv cable was impossible. Use of 69 kv cable began in the United States in Cleveland during 1924 and in Chicago and Philadelphia during 1926. Its operating record is now fully as satisfactory as that of cables operated at lower voltages.

Ionization and Stability

While marked improvements were being made in the initial properties of the insulation, attention also was focused on the deterioration that occurred in the insulation with time in service. The principal cause of this deterioration was ionization of gaseous or vacuous voids within the insulation. This source of trouble was exploited first by Proos, Smit Kleine, and van Staveren[7] of Holland in 1923. An ionization factor clause was used first in American speci-

Fig. 11. Operating record of 1,085 miles of 13-kv 3-conductor cable showing decrease of rate of insulation failures and of average power factor of cable insulation

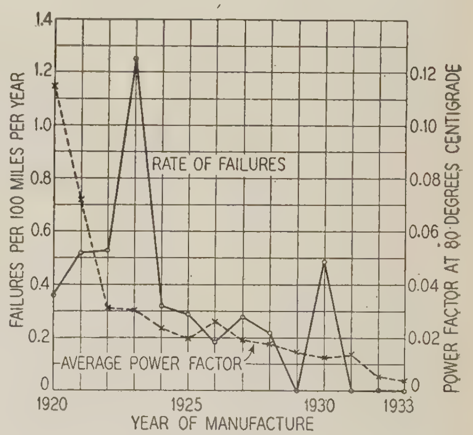


Table I—Comparison of 500,000-Circular Mil 3-Conductor 12-Kv Cable Made in 1920 With That Made in 1934

Year Made	1920	1934
Thickness of insulation, 64ths of an inch		
On each conductor	12	9
Over all 3 insulated conductors	8	5
Maximum allowable operating temperature, degrees centigrade	73	77
Power factor of dielectric at maximum allowable temperature	0.18	0.01
Carrying capacity in summer, kilovolt-amperes	6,680	7,610
Cost per mile of line under present conditions	$11,350	$10,190
Cost per mile per kilovolt-ampere	$ 1.70	$ 1.34
Estimated annual cost of dielectric losses per mile	$ 37.00	$ 7.64

fications in 1924. Figure 12 shows that the American manufacturers improved this property of the insulation rapidly after they learned how to measure it by a comparatively simple test that could be applied to each reel of cable in the factory. Before this test was devised, the only method of determining whether the insulation was subject to deterioration from this cause was to submit the cable to a long-time test and to note the visual changes in the insulation after the test.

At present, the stability of the insulation can be measured only by placing the cable in service and noting the results over a long period of years, or by an accelerated aging test, a very expensive test requiring several weeks or perhaps months in order to secure the desired results. The improvements in dielectric loss and in ionization following the development of suitable means of measuring these properties by a comparatively simple test, as depicted in figure 12, indicate that the manufacturers would make a similar rapid improvement in the stability of the insulation following the discovery of some method of measuring the stability by means of a laboratory test comparable in simplicity with methods of measuring dielectric loss and ionization factor.

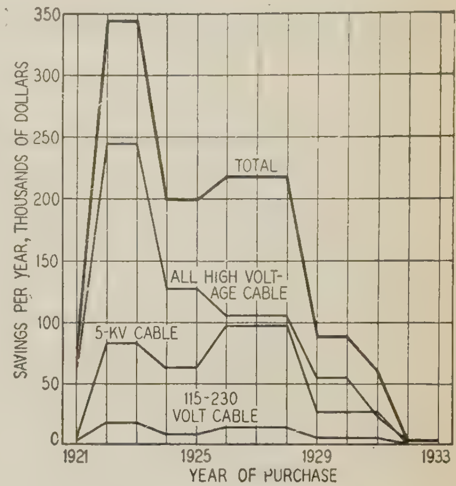
Reduction in Thickness of Insulation

If the stability of the insulation could be insured so that the initial properties of the insulation could be maintained over a long period of years, then the thickness of the insulation for the higher voltage cables could be reduced radically, thus resulting in further reductions in the cost of the cable. The extent to which further reductions in the thickness of insulation may be carried is indicated by the action of one English manufacturer who has furnished for a 66 kv line in England cable having 15 per cent less insulation than any 66 kv cable now in operation in the United States. If this manufacturer can find sufficient warrant from the present rather crude methods of measuring the stability of insulation to reduce the thickness by 15 per cent, it would appear that a further reduction of about the same amount might follow in a few years the development of a laboratory method of measuring the stability of impregnated paper insulation.

Recent carefully made estimates indicate that in the past 13 years the Commonwealth Edison Company has saved about $2,000,000 by using on its lead covered cables less insulation than other companies operating at the voltages now being used on the various transmission and distribution systems of the company. Distribution of the saving by years and voltage class is shown in figure 13. A liberal estimate of the cost of the investigations that made possible this saving is $300,000. The results of these investigations have been beneficial also in connection with other cables. This saving is probably greater than the gain that can reasonably be expected during the next 13 year period. It shows, however, what can be done by means of such tests in following and taking advantage of improvements in quality as they develop.

While some further reductions in insulation thickness probably will be made from the information obtained by the tests used at present, the indications are that larger reductions will follow a new test for stability.

Fig. 13. Savings effected by Commonwealth Edison Company by using on its cables less insulation than was used by other companies for operation at comparable voltages



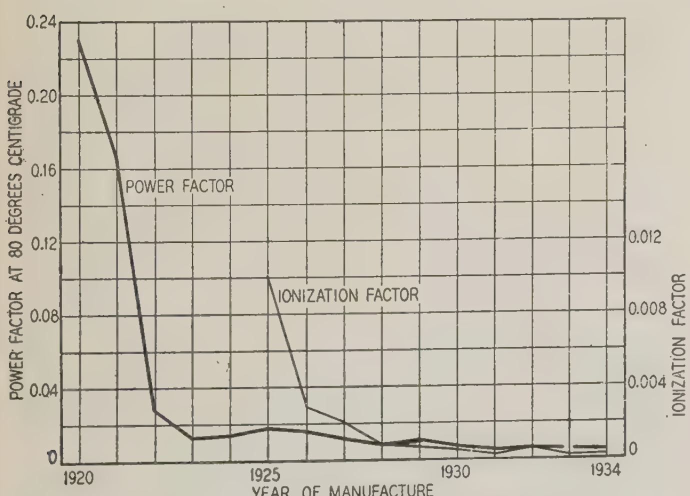


Fig. 12. Average power factor and ionization factor of 13-kv 3-conductor cable of one make

Note sharp reduction immediately following the development of suitable means of measuring these properties

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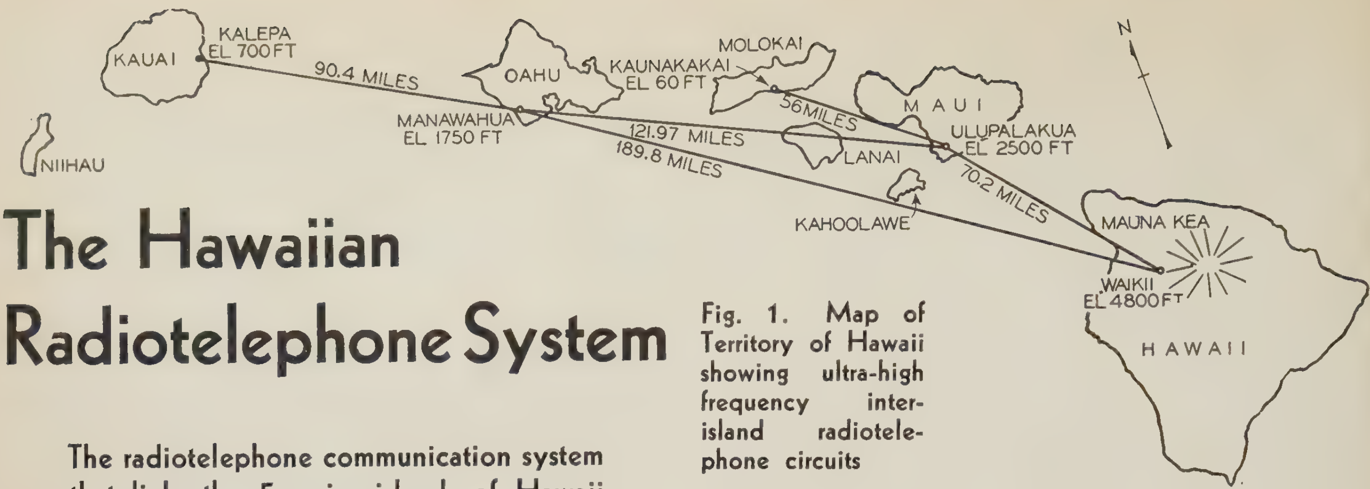

The Hawaiian Radiotelephone System

Fig. 1. Map of Territory of Hawaii showing ultra-high frequency inter-island radiotelephone circuits

The radiotelephone communication system that links the 5 major islands of Hawaii and some of the engineering problems involved in developing it form the subject matter of this paper. This system, which has been in successful operation for more than 3 years, operates on frequencies between 30 and 60 megacycles per second, although in April 1935, an experimental circuit operating on 220/230 megacycles was placed in service. The successful operation of this system has shown that ultra-high frequencies are well suited to short quasi-optical ranges and that reliable semi-nonattended radiotelephone services are practicable.

By
W. I. HARRINGTON
NONMEMBER
Mutual Telephone Co.
Honolulu, Hawaii

C. W. HANSELL
ASSOCIATE A.I.E.E.
R. C. A. Communications, Inc., Rocky Point, N. Y.

FOR many years there had been a need of joining the islands of Hawaii with telephone circuits, and the Mutual Telephone Company of Honolulu had been seeking a practical means of accomplishing this end. The presence of coral reefs, the depth and configuration of the ocean bottom, and the constant pounding of the waves made undersea cables impracticable. Consequently the company turned to radio to find a solution of the problem, but for many years even radio was not capable of providing circuits at a cost that the service could afford. Surveys were made with frequencies lower than 3 megacycles per second, but atmospheric disturbances and selective fading on these frequencies were too great to permit establishing a service. A solution finally was found by the application of frequencies higher than 30 megacycles.

Since 1924 the Radio Corporation of America has engaged in a continuous development program for the purpose of providing equipment to operate at higher and higher frequencies and of utilizing this equipment in determining the propagation characteristics and potential usefulness of these higher frequencies. By 1928 this work had progressed sufficiently to indicate that frequencies between 30 and 100 megacycles per second would reach considerable distances beyond the optical range and that, by placing transmitters and receivers at elevated points, distances of from 100 to 200 miles could be reached. At the same time it had been demonstrated that, unlike frequencies between 2 and 30 megacycles, signals transmitted at frequencies of 30 to 100 megacycles would neither be heard nor produce interference at great distances.[1]

On July 13, 1928, the Mutual Telephone Company instigated negotiations with the Radio Corporation of America which led to a joint investigation of the possibilities for setting up interisland radiotelephone circuits. Some experiments with very high frequencies already had been made by the Mutual Telephone Company, which indicated that such frequencies might be used to solve the problem if sufficient improvement could be obtained with directional antennas and if transmitting and receiving equipment with sufficiently constant frequencies could be obtained. It was agreed, therefore, that a trial would be made with frequencies somewhat higher than 30 megacycles.

Transmitter Design

At the time this work was undertaken there was no recognized simple means for obtaining constant frequency in transmitters having outputs with frequencies higher than 30 megacycles. Frequency control by means of piezoelectric quartz crystals had been developed for lower frequencies, but the use of this method for frequencies higher than 30 megacycles would have involved an excessive number of frequency multipliers and amplifiers, which would have resulted in greater expense and less reliability,

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1. For all numbered references see list at end of paper.

and would have required more expert operating personnel.

In attempting to provide simple semiportable equipment for the surveys in Hawaii, 2 transmitters were constructed, at the transmitter research and development laboratory of the Radio Corporation (Rocky Point, N. Y.) having their frequencies stabilized by means of a portion of 2-conductor radio-frequency transmission line. A simplified schematic diagram of the transmitter is shown in figure 2, and a photograph in figure 3.

In this arrangement 2 type 852 tubes were used in a balanced or push-pull circuit. Regeneration was obtained by the coupling between output and input circuits through the anode to grid capacitances of the tubes. During oscillation the output coil and the line each acted as effective inductances of such a combined value as to balance the anode to grid capacitances. Under these conditions the radio frequency anode and grid voltages of each tube are opposite in phase, with respect to the cathode, which is the well known condition required for oscillation. The regeneration was adjusted by varying the output coil and the length of line in such a way as to produce equal and opposite changes in inductance and no change in frequency. The oscillatory energy in the line was adjusted by varying the length of line until substantially minimum frequency modulation from a-c cathode heating and a-c components of anode supply current was obtained. The line passed through equal values of effective inductance at lengths differing by a half wave or multiples of a half wave. For survey work an open wire line of number 6 copper wires, spaced a few inches, was used. This type of line has a power factor of about 0.0005 to 0.0007, depending upon the frequency, in the band between 30 and 60 megacycles.

As a result of its low power factor, the line formed a sharply resonant or highly selective grid circuit for the oscillator and was found to be quite effective in reducing undesired frequency modulation and variations in mean frequency. It permitted the use of alternating current cathode heating and reduced the transmitter circuits to the simplest possible arrangement. Subsequent developments of line control, starting with these transmitters, have provided one of the most promising means of frequency control for very high frequency transmitters.[2,3]

Receiver Design

Receivers used for field surveys were of the superheterodyne type constructed in 2 units. Figure 4 shows the first unit of one of the receivers. The unit contained 2 stages of tuned radio frequency amplification followed by a heterodyne detector. The radio frequency amplifiers utilized special screen grid tubes designed for operation at frequencies higher than 30 megacycles. With the aid of these tubes and careful shielding and arrangement it was possible to obtain considerable amplification, which would have been impossible with any arrangement of standard tubes then available.

The second unit consisted of a modified aircraft beacon receiver. The high gain and high working frequency (270 to 500 kilocycles) of this receiver made it particularly suitable for use as an intermediate frequency amplifier, detector, and audio amplifier. The circuits in the receiver consisted of 3 stages of tuned intermediate frequency amplification utilizing screen grid tubes, oscillating detector, and 2 stages of high quality audio amplification.

Directional Antennas

At the time the survey equipment was provided there had been developed recently a new type of directional antenna consisting of 4 wires, each several wave lengths long, arranged in one vertical plane and interconnected in such a way as to produce a substantially unidirectional beam of radiation. Figure 5 is a diagram showing the arrangement of this antenna.[4]

As usually constructed this type of antenna produces radiation in the direction of the beam about 16 times greater in intensity than would be produced by the same amount of total power radiated from a simple antenna. When used for receiving the antenna gives an equivalent power gain. The overall gain obtained by using these antennas at both transmitter and receiver is about 250 to 1. Proportionally larger gains may be obtained by paralleling or broadsiding more than one of these antennas into one highly directional system.

Antennas of this type were used in connection with field surveys and later for setting up commercial circuits.

Field Surveys

In August 1929, 2 transmitters, 2 receivers, and a gasoline engine driven generator to supply power at isolated survey points were taken to the islands. Tests were begun in September with a transmitter located on a knoll on the southern slope of Puu Manawahua, Oahu, at an elevation of about 1,700 feet. The results of these tests already have been described.[1]

Frequencies in the neighborhood of 37.5 megacycles were selected as best for the Oahu-Hawaii circuit, the longest in the desired interisland system. There was no doubt in the minds of all the observers that, with the aid of directional antennas, thoroughly

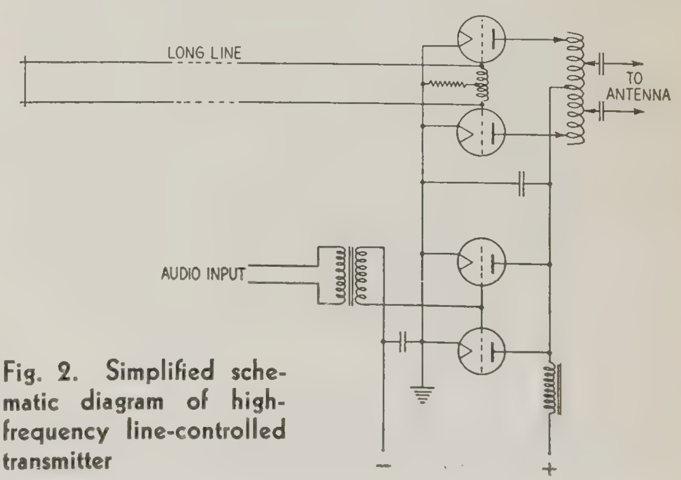

Fig. 2. Simplified schematic diagram of high-frequency line-controlled transmitter

commercial interisland radiotelephone circuits could be established. Accordingly, a 2 way radiotelephone circuit was set up between Puu Manawahua, Oahu, and Waikii, Hawaii, using directional antennas. An extended period of 2 way testing then demonstrated the commercial feasibility of the circuit.

Additional tests were made over the other proposed circuits which confirmed the conclusion that commercial circuits were practicable. At sea level on Kaui it was possible to receive the Hawaii transmitter over a record distance of 280 miles. This result was attributed to the use of directional antennas and to favorable conditions.

Successful performance of the interisland circuits having been assured, arrangements were made to obtain commercial equipment. This equipment followed the general design of the survey equipment fairly closely. Significant changes in design included the selection of a completely shielded frequency control line for the transmitter and a band width of 50,000 cycles for the receiver. The broad receiver band width made frequent attention to correct for transmitter and receiver frequency drift unnecessary and was essential for economical operation.

By careful design and selection of frequencies it was possible to operate both transmitters and receivers at each terminal in the same building. This greatly simplified operation and maintenance.

Honolulu to San Francisco Circuit

Within a few weeks after the interisland radiotelephone system was placed in operation a radio telephone circuit was opened between Honolulu and San Francisco, Calif., through the facilities of R. C. A. Communications, Inc., in Hawaii, and the facilities of the American Telephone and Telegraph Company in California. The transmitter for the Hawaiian end of this circuit is located in the transocean station at Kahuku and the receiver is located at Koko Head. They are joined through wire connections to the central telephone system of the Mutual Telephone Company in Honolulu.

On the California end of the circuit the transmitter is located at Dixon and the receiver at Point Reyes, from which points wire line connections extend to San Francisco. From San Francisco wire connections can be made to any point in the United States and by wire and radio to nearly all other points in the civilized world.

The circuit is operated on frequencies between 5 and 20 megacycles and with carrier power ranging from 5 to 20 kw. Directional antennas are used for transmission and reception at both ends of the circuit. As a result of the favorable circuit conditions and the characteristics of the equipment, this circuit has proved to be one of the most consistent and reliable of long distance radiotelephone circuits in existence.

Commercial Operation

Before discussing the operating characteristics of the System, a brief general description of the plant as a whole will be given. Reference to a map of the Territory of Hawaii, figure 1, will show that the group consists principally of 5 major islands: Oahu, Hawaii, Maui, Molokai, and Kauai. The Mutal Telephone Company owns and operates telephone systems upon these 5 islands and, in considering methods of interconnecting the 5 systems, was faced with several problems. It may be seen from the map that the islands are ideally situated for quasi-optical circuits, and some of the problems involving selection of station sites, frequencies, etc., and the design of suitable apparatus and antenna systems, have been described previously.

After it had been demonstrated to be technically feasible to establish the desired circuits utilizing ultra-high frequencies, there remained for consideration the requirements of economic operation, which in themselves presented several technical problems. In figure 6 is shown a block diagram of the system, on which are indicated the circuit frequencies and the number of telephones on the various islands to be connected. It may be readily understood that the system to be economically practicable, with this comparatively small number of subscribers, must be capable of operation at a minimum of expense. This requirement is emphasized by the rather large capital investment required to erect stations at the isolated mountain sites necessitated by altitude and optical path considerations.

Some of the technical problems presented thus were: The transmitters and receivers must be capable of operation in one building, to reduc eoperating and maintenance personnel; antenna systems must

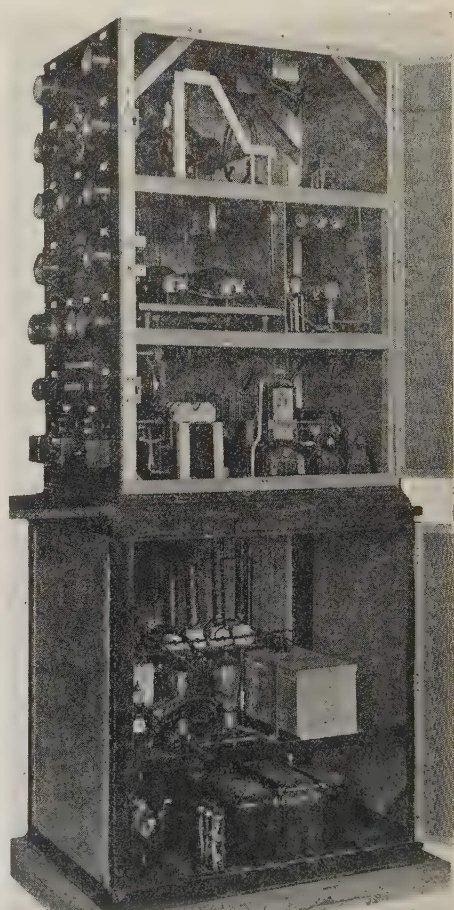

Fig. 3. High frequency survey transmitter

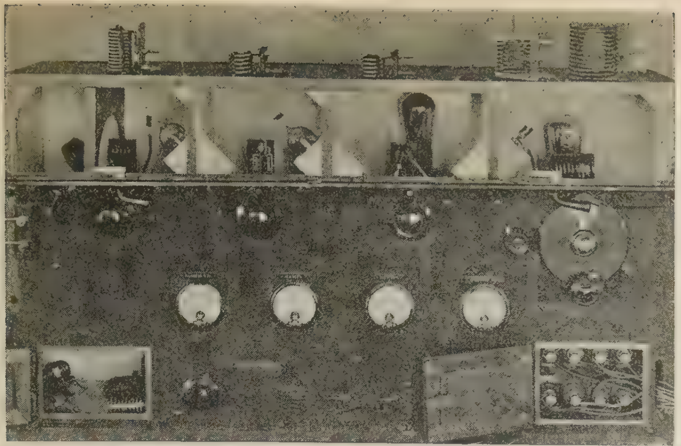

Fig. 4. High frequency unit of survey receiver

be adapted to the same type of operation; transmitters and receivers must have a degree of frequency stability and ruggedness sufficient to permit semi-nonattended operation; received signal levels should permit the use of automatic volume control and preclude, in so far as possible, the necessity for constant manual gain control. Some of these problems were worked out in the design and installation of the equipment and antenna systems, but others could be met and solved only in the light of operating experience.

A few weeks of operation were sufficient to show that the over-all frequency stability of the circuits would permit the use of remote control and semi-nonattended service, which was highly desirable from the standpoint of operating economy. Accordingly, a method was devised whereby the telephone operators at the various exchanges might have control of the transmitters at the associated radio stations. As the system now is operated, the plate supply circuits of the transmitters are shut down between calls during the day, and at night the entire transmitter is so controlled.

When making the installation of this equipment, it was desired to keep the technical personnel at the minimum consistent with good service. Therefore, technical monitoring of calls is not attempted. The input transformers, or hybrid coils, necessary to a 2 wire circuit were installed at the radio stations, and 2-wire channels were extended to the control telephone exchanges; from there the calls are distributed throughout the lines of the company's system. This arrangement cuts the number of lines required to a minimum, but has the disadvantage that technical monitoring, if required, would have to be accomplished at the radio station; this, however, has not been found necessary. Transmitter input and receiver output are adjusted to the optimum value for average calls, and further adjustments for individual calls are not made except that 2-way repeaters are installed in the Honolulu and Hilo exchanges, and monitoring operators may increase the speech frequency volume 6 decibels when required. Pads also are installed at the control exchanges in order that volume may be reduced when connecting local subscribers.

While this method is a compromise in favor of reduced personnel it is working quite satisfactorily in the present system where there are no extremely long lines or subscriber's loops, and where the general speech volume is at a fairly constant average level. Should future developments warrant or require the addition of constant monitoring of calls, it could be accomplished by extending 4-wire circuits to the control telephone exchanges and providing there means of regulating transmitter input and receiver output. This method would not necessitate increasing the technical personnel at the radio stations, which are necessarily in isolated locations where the maintenance of large staffs would be expensive.

At present, each station is staffed with one skilled technical and maintenance man and one student-assistant, who is capable of taking over the station for short periods and doing routine maintenance work. For the most part, the circuits operate without constant supervision, and the station staff is free to carry on the general maintenance work during circuit hours.

That this system of semi-nonattended operation is satisfactory from the subscribers point of view is indicated by a study of the general quality of calls. For this purpose, all calls are classified by the supervising operator into 4 groups:

A. Good talk; no repetitions necessitated by circuit faults; no noticeable noise.

B. Conversation satisfactory; very few repetitions; slight noise or low level transmission.

C. Fair talk; some time deductions for repetition; circuit noisy or level low.

D. Poor; noisy or weak, necessitating large time deductions or reconnection.

During the past 3 years of commercial operation approximately 45,000 paid calls were handled over the system, and of this number 96.5 per cent were rated "A," and 98.3 per cent fell within the "A" and "B" classification.

Privacy

At the present time no inverters or other "scrambling" devices are used on the circuits. All stations are located on mountain sides, well remote from centers of population, and the sharply directional beams from the directional antennas pass well over any such centers. Efforts at interception with carefully constructed receivers were made, with entire lack of success. No instances of interception by unauthorized parties, of any interisland radiotelephone calls have come to the authors' attention, and no reports or rumors of such an occurrence have been circulated. It is felt that this record, covering a period of over 3 years' operation, may be accepted as proving definitely that the inherent qualities of the system offer complete privacy of calls. The absence of any technical activity in the ultra-high frequencies in the Territory tends to assist this condition.

Receiver Plate Supply System

As originally installed, the receiver plate supply consisted of a double-bank 250-volt lead-acid battery

at each station, but the maintenance and replacement expense on this large number of small cells, especially when operated on a charge and discharge basis, led to experiments with various plate supply systems in the hope of obviating this large expense. This problem was made difficult by the fact that the receiver frequency stability requirements necessitated a plate supply having extremely good regulation. Recent developments in rectifier tubes and electrolytic condensers, however, made possible the construction of heavy duty a-c power supplies, which have been giving satisfactory service for the past 18 months.

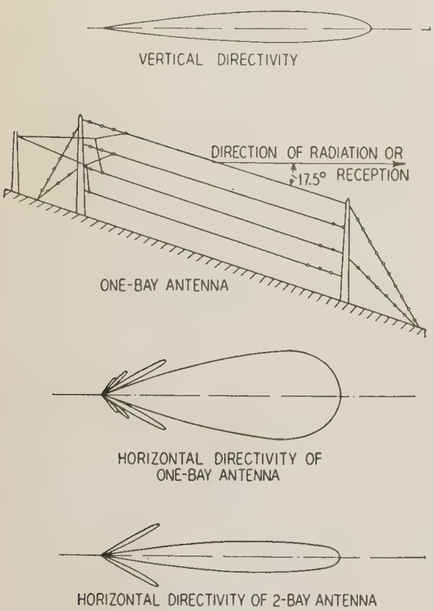

Fig. 5. Schematic diagram of directional antenna and directive characteristics

Interference

Interference problems on this system have been very few because of the isolated location of the stations, the directional characteristics of the receiving antennas, and the fact that the more common types of interference do not affect the ultra-high frequencies to the same extent as the lower frequencies. One notable exception has been the interference experienced from nonshielded air-plane engines which at times has reached fairly serious proportions. Tests on this type of interference have shown that the sensitive receiving arrays used are capable of picking up noise from this source over a distance of 10 miles. The gradual replacement of the nonshielded type of plane, to-gether with the co-operation of the army and navy air services in restricting their flying in the affected areas, however, has kept this type of interference at a minimum.

Interference from natural electrical disturbances seems to have little effect on the frequencies in use. Instances have been noted when severe electrical storms have originated near the stations without causing noticeable interference. In one instance the disturbance was so severe as practically to paralyze radio communication throughout the Territory on all frequencies lower than 30 megacycles; yet the ultra-high frequency radiotelephone scarcely was affected at all.

Fading

Data on fading characteristics on these circuits necessarily is limited by the use of remote control and nonattended operation, but such information as is available indicates that the frequency and severity of fading is directly proportional to the amount of intervention of earth surface between transmitter and receiver. Fading is most noticeable on the Oahu-Hawaii circuit over a distance of 190 miles, with approximately 70 miles of intervention, and practically nonexistent on the Oahu-Maui circuit with 13 miles of intervention in 122 miles. On the Oahu-Kauai circuit over 90 miles, with approximately 35 miles of intervention, the fading is less prevalent than on the Oahu-Hawaii circuit but more frequent than on the longer Oahu-Maui circuit.

Such fading as has been noted has been practically all of the same nature and usually of 3 or 4 minutes' duration, accompanying a period of general instability lasting from 15 minutes to an hour. Uusually, the automatic volume control is able to compensate for fading, and such periods are characterized only by a relatively high noise level on the circuit affected; occasionally, however, the fading is sufficiently severe to interrupt service for a short time. It has been impossible to determine any diurnal relationship to this fading because of limited data, but all observations indicate that it may occur at any time during the day or night. It is noted frequently that one circuit may be subject to erratic fading conditions, while other circuits are not affected at all; at other times, all circuits are affected simultaneously.

An entirely different fading characteristic has been observed on the circuit between Hawaii and Maui. This circuit is 70 miles long and enjoys a complete optical path. The fading periods were comparatively rapid in recurrence and maintained a fairly definite time interval—the signal swinging in and out at a rate of approximately 20 times per minute, frequently over a period of an hour or more. Investigation showed that this condition was caused by a twist in polarity of the wave front, and the phenomenon was exaggerated at the receiver by the strongly vertical characteristics of the directional receiving antenna. Experiments with a portable doublet antenna showed that while the wave might be polarized horizontally at the directional antenna, it would return to a vertical position a few hundred feet further along the wave path. The condition finally was corrected by the use of a very long harmonic wire receiving antenna.

Connections to Transpacific Radiotelephone

On December 23, 1931, the Mutual Telephone Company system was connected with the American Telephone and Telegraph Company system through the radiotelephone circuit between Honolulu and San Francisco, Calif. From San Francisco the service is extended through the American Telephone

and Telegraph Company's facilities to the North American Continent, and through other radiotelephone circuits, to many foreign countries. On the Hawaiian end, the service is extended through the ultra-high frequency system to the other islands of the group. As a result of the excellent transmission characteristics of the 2 systems, interconnections have been very successful. During the past 3 years about 700 commercial calls have been transferred from the interisland system to the mainland and to foreign countries, and they have enjoyed a very high transmission rating. For these connections, a straight 2 wire patch is made at the Honolulu control board.

Program Transmission and Relaying

There has been some call for use of the interisland circuits in handling broadcast programs originating on the outlying islands; and while neither the apparatus nor the telephone lines involved are designed for high quality program transmission, some quite successful connections have been made. Notable among these was the recent broadcast of the ceremonies attending the opening of the new highway to the summit of Haleakala Crater on the Island of Maui. In this instance the program originated at the top of Haleakala and was transmitted to Honolulu over the ultra-high frequency circuit, and there bridged to a local broadcasting station and to the R.C.A. short wave station at Kahuku, Oahu. The signal from Kahuku was picked up at San Francisco and transferred to the network of the National Broadcasting Company. The broadcasting company gave the program a rating of 95, which is considered excellent.

The circuit between the islands of Maui and Hawaii frequently is used to provide an additional circuit from Oahu to Hawaii, via Maui, or to Maui via Hawaii. This forms a valuable adjunct to the service as a whole not only in handling overflow traffic during rush hours, but as an emergency circuit in the event of failure of a direct circuit. This relay has proved quite satisfactory, and the general quality of conversations compares favorably with those over a single circuit. In the original set-up, the circuits were patched together at the telephone exchange controlling the Maui radio station; but since this 2 wire patch left 2 possible singing paths in the circuit, it was considered desirable to effect a 4 wire patch at the radio station. From personnel considerations it is not practicable to call upon the station staff to perform this patching operation; so an automatic patching device was designed, utilizing a series of relays actuated by an automatic telephone selector switch. With this device the telephone operator, by dialing different numbers, may set up either circuit individually or patch the 2 together at the radio station. Since one singing path is eliminated by this method, it is possible to operate the 2 circuits at a higher level, and considerable improvement in quality is effected.

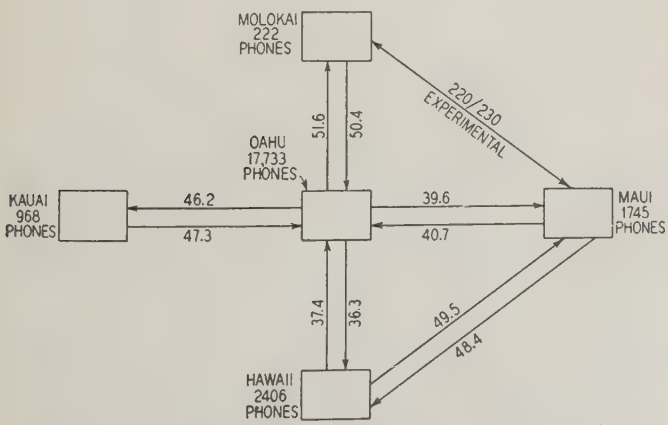

Fig. 6. Circuits and frequencies (in megacycles per second) used for Hawaiian interisland circuits

New 220/230 Megacycle Circuit

On April 22, 1935 the Mutual Telephone Company placed into operation an experimental circuit between the islands of Molokai and Maui operating on frequencies of 220 and 230 megacycles. This circuit now is operating on a commercial basis through special permission granted by the Federal Communications Commission; it is hoped, by this means, to accumulate valuable data on the transmission characteristics of these frequencies. The Maui end of the circuit is located at the interisland ultra-high frequency station at an altitude of 2,500 feet, and the Molokai end at the company's wireless telegraph station at Kaunakakai, which is at sea level. An optical path 56 miles in length exists between the 2 points.

Technical considerations that influenced the selection of frequencies in the neighborhood of 230 megacycles for this circuit were those of automobile ignition interference, directional antennas and their cost, interference between transmitter and receiver operated in the same building, and interference from the wireless telegraph plant.

The Molokai end of this circuit was placed at the present wireless station to effect a desirable economy in personnel and plant property. This site is on a well traveled country highway and several interference problems were presented. Experiments developed the fact that frequencies in the range of 150 to 400 megacycles are relatively unaffected by automobile ignition interference, and it was found possible to eliminate noise from this source entirely with directive antennas elevated 30 or 40 feet. No interference is experienced from the wireless telegraph transmitter, operating on 5,750 kilocycles, and located about 100 feet from the receiving antenna.

The transmitting antennas consist of half wave doublets located at the focus of quarter wave parabolas. These parabolas are supported on towers 50 feet from the ground and are fed through 240 ohm transmission lines. The transmitters are of the modulated oscillator type, utilizing 2 type 800 tubes in a push-pull arrangement, with approximately 50 watts input. Long resonant grid lines are used for frequency control and have proved highly satisfactory at these frequencies.

Several types of receivers are being tested, in-

cluding superregenerative and superheterodyne arrangements. A superregenerative affair utilizing the new type 955 tube has proved most satisfactory to date. The field laid down by the transmitter is so great that extremely sensitive receivers are not required, and more attention is being given to stability and noise suppression than to sensitivity.

Frequencies are checked by harmonic methods, from the standard frequency transmission of the U.S. Bureau of Standards. An electron coupled oscillator set at 10,000 kilocycles is used to generate harmonics, which are amplified and beat against the transmitters in a carefully shielded receiver. The frequencies were selected purposely at 10,000 kilocycle harmonics to facilitate these measurements. At the present time no attempt at constant frequency monitoring is made, but the weekly checks so far have shown that the control method used should be entirely adequate.

Economic Considerations

Since so many of the engineering problems presented in establishing a communication system are created by economic necessity, it might be of interest to outline briefly some of the commercial features of the system under discussion.

At the time the interisland radiotelephone circuits were placed in commission, the Mutual Telephone Company was operating an interisland wireless telegraph system linking the islands of Hawaii, Maui, Kauai, Molokai, and Lanai, to Oahu, and the new radio telephone circuits entered into active competition with this existing system. At this time, the wireless telegraph department offered service from 7:30 a.m. until midnight daily, employing 2 licensed wireless operators at each station. With the radiotelephone department offering 24 hour service at rates comparable to the amount required for a telegraph message and an answer thereto, it was to be expected that the wireless telegraph system would sustain a considerable loss in traffic. To offset this expected loss, the night operators were replaced with lower salaried clerks who accept telegraph traffic and effect delivery by means of the radiotelephone. Operating under this arrangement, the telephone system has carried an average of 7,000 messages per year in addition to its subscriber load of approximately 15,000 calls.

The entire population of the Territory of Hawaii is 378,948, of which number 207,000 reside in Oahu. The number of paid calls since the circuits were opened has averaged 15,000 per year, and average gross revenue per year has been $50,000. The total capital investment of the system is approximately $332,000. From these figures it may readily be seen that an attempt to produce adequate return from such a system must present some unique engineering problems, not necessarily encountered elsewhere.

The 3 years of operation of this system have shown that the ultra-high frequencies are well suited to short quasi-optical ranges, and that reliable seminonattended radio telephone services are practicable. It is believed that the practical demonstration of these possibilities may help to advance the application of these frequencies.

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Ship-to-Shore Radio in Puget Sound Area

Telephone communication to and from harbor craft in the Puget Sound area in the State of Washington is accomplished by means of low powered radiotelephone channels from each boat to a single land station from which connections can be made to any telephone; the equipment used for this purpose is described here. A 400 watt transmitter is used in the land station and a 50 watt transmitter on each boat. Frequencies used are 2,522 kilocycles for the shore-to-ship direction, and 2,126 kilocycles for the ship-to-shore direction.

By
E. B. HANSEN
ASSOCIATE A.I.E.E.

Pacific Tel. & Tel. Co., Inc., Seattle, Wash.

TELEPHONE communication in its various phases has become so highly developed in recent years that regardless of the degree of isolation in which an individual finds himself, the commonplace habit of always being able under normal conditions to establish telephone contact with anyone he desires results in demands that require specialized treatment by the communication engineer. Such a demand arose among the ship owners operating within the Puget Sound area in the State of Washing-

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ton. This large inland body of salt water extends in the United States about 150 miles from the international boundary on the north to its southern end at Olympia. Its average width is approximately 50 miles with outlets to the Pacific Ocean through the Strait of Juan de Fuca and Georgia Strait. Hundreds of islands are within the confines of the sound, ranging in size from mere rock juttings to an island (Whidby) that is the second largest in the United States.

Puget Sound serves a large area the principal resources of which are lumber and fishing. Movement of the raw products to points where the manufacturing and processing is carried on comprises a major part of the short haul shipping in the Puget Sound area. Large lumber and pulp mills have been established permanently at locations where deep sea shipping and rail facilities are readily available. Logs in the form of large booms are towed to the mills from the sources of supply which extend throughout the area drained by Puget Sound. The average haul of each boom is about 75 miles and consumes several days. Because of the relatively long time a tug is isolated in each operation, it is evident that some economical means of dispatching and directing the activities of the tow boats from the land headquarters is desirable. In fishing, there is an even greater need than in log towing for close contact between boat and land, in order that both the fishing and cannery activities may be co-ordinated so as to prevent wastage of fish during large runs.

From the foregoing, it seems clear that some means of communication between harbor craft and land stations would be useful. A preliminary view of the problem indicated that low-powered radiotelephone channels from each of these boats to a single land station from which connections could be made over land wires to any telephone appeared to be the most economical and practical means from the standpoint of the ship owners. Furthermore, the government regulations covering the issuance of operators' licenses for radiotelephone transmitters of 50 watts or less power are such that the average member of a ship's crew can qualify after a few hours instruction, thus making it unnecessary for vessels employing this equipment to carry a special radio operator.

Selection of Land Station Site

After it was decided that this service was feasible and should be established, the initial order of procedure was the selection of the site for the land station. This involved consideration of the following primary factors: radio transmission or coverage, freedom from interfering noise, proximity to other radio stations, power supply, telephone wire connections, availability of land and housing facilities, and, of course, the cost of each of these items.

Radio Transmission

The radio transmission requirements for the land transmitter are of prime importance, as it is essential to locate the transmitter so as to provide adequate

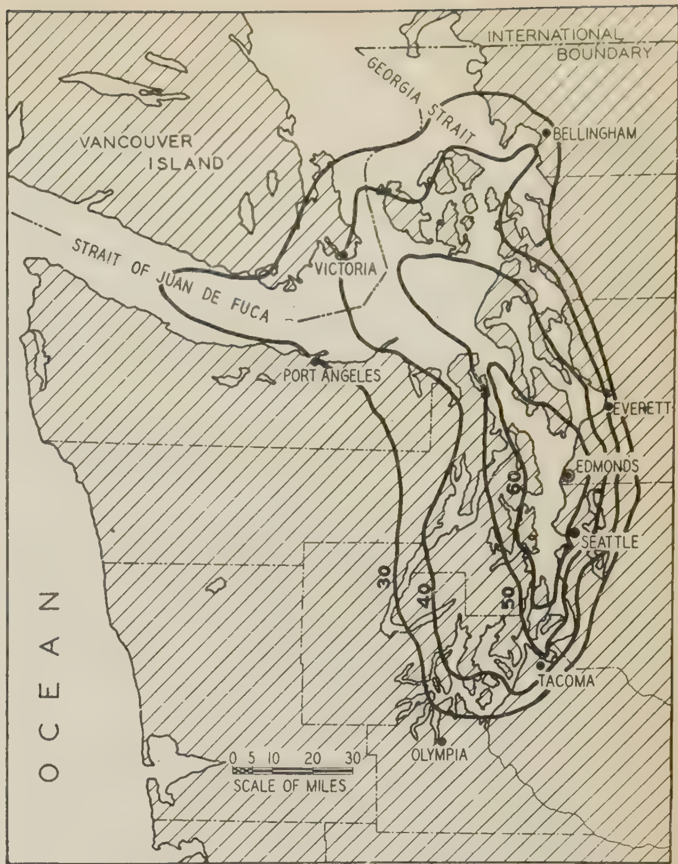

Fig. 1. Field strength contour map of Puget Sound and vicinity

Measurements made with 50 watt transmitter at the Point Edwards (near Edmonds) site. Figures on contour lines indicate field strength in decibels above one microvolt per meter

signal strength to the area that must be covered. For the distances involved in the harbor area it is advantageous to make use of a frequency that will permit covering the entire area with the direct or "ground" wave. The frequency assigned by the Federal Communications Commission for the Puget Sound shore-to-ship transmission is 2,522 kilocycles, and for transmission in the ship-to-shore direction 2,126 kilocycles. When it can be used alone, the ground wave is usually superior from the standpoint of quality and freedom from fading. The signal strengths obtained with ground wave transmission, however, are affected considerably by the terrain in the transmission path. For example, the daytime range of a 50 watt transmitter may be 150 miles over water while over land it may be less than 15 miles. Furthermore, because of the characteristics of overland transmission in which the attenuation in the first mile or 2 is much greater than in succeeding miles, the location of the shore station a mile back from the shore reduces the over-water range to 50 miles. The first requirement, therefore, was that the shore station be located as close to the water as possible. Calculated field strength distribution patterns were made for various tentative locations of the radio station. These predictions, however, were checked by an actual field strength survey.

At the locations that appeared from the theoretical

study to be most promising as to radio transmission performance, a 50 watt transmitter was employed to radiate a known power. Calibrated receiving apparatus was taken to various locations in the Puget Sound area by boat and automobile and the signal field strengths in decibels above 1 microvolt per meter were determined. The detailed method of making such measurements has been covered in previous published information.[1,2,3] It is sufficient, therefore, since no unusual problems arose in this connection, to show the results obtained with the transmitter at the site finally selected as best fulfilling the requirements. These results are shown on figure 1.

Interfering Noise and Other Radio Stations

From the standpoint of reception, it is necessary that the location of the receiving station be free from noise. The main sources of noise other than atmospheric disturbances, are from certain types of high voltage electric power systems, street cars, electrical machinery with varying load, and ignition systems of automobiles, motor boats, etc. These sources are of a variable nature, and the only really satisfactory method of determining how free a site is from noise is to make measurements at various times of the day to determine the field strength required for commercial circuits. In general, the daytime noise should be low enough to permit commercial circuits with field strengths of from 15 to 30 decibels above one microvolt per meter, depending, of course, upon the coverage desired. It was found generally that the receiving antenna should be at least 300 feet from automobile highways and 1/4 mile or more from high voltage power transmission lines. Measurements of noise and of interference from other radio stations were made, and the site selected was found to be extremely free from all sources of interference.

The site selected as fulfilling the foregoing requirements in addition to having power supply and telephone wire connection available is on Point Edwards about one mile south of Edmonds, Wash. The plot contains about 13 acres of tide and harbor land and has a shore line of approximately 1,300 feet. While the land is flooded to a depth of several feet during high tides, about half of it may be utilized in the future for antenna construction without excessive cost.

Housing and Antenna System

The building housing the transmitter and receiver is of wood frame construction erected on treated piling.

The transmitting antenna is of the simple vertical type, 80 feet high and supported by a single pole 110 feet high. This pole also is supported by piling and is adjacent to the building. The receiving antenna is of the vertical type, 40 feet high and located 200 feet from the transmitting antenna; it also is supported by piling. A tuning unit is mounted in a weather-proofed box on the receiving antenna pole.

1. For all numbered references see list at end of paper.

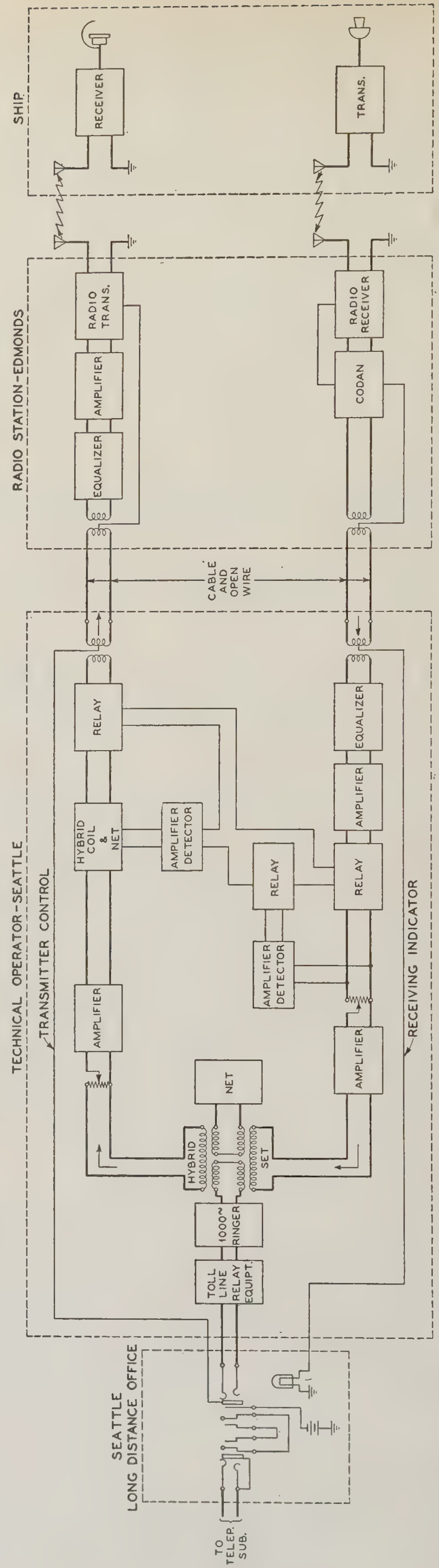

Fig. 2. Schematic diagram of Puget Sound harbor-craft ship-to-shore radiotelephone circuit

The transmission line from the receiving antenna to the receiver in the radio equipment building is a special armored and lead covered concentric conductor type.

Equipment

Equipment at the land stations consists of a 400 watt transmitter with a rectifier unit for power supply similar to the type generally used for aviation service. Frequency stability is obtained by the use of a quartz crystal frequency control which will maintain its frequency to better than 0.025 per cent. It is designed for substantially complete modulation of the carrier, and under this condition little distortion occurs to the speech frequencies. A tuning unit for tuning the transmitting antenna to resonance also is housed in the building. The radio receiver is of a superheterodyne type having a high degree of sensitivity and selectivity and was designed primarily for use in marine radio telephone service with small boats. Associated with the receiver is a "codan" (carrier operated device anti-noise) which serves to cut off the output of the receiver when no carrier signal is being received from a ship station. During such periods, the automatic gain control permits the receiver gain to increase to its maximum value, and if the "codan" were not used this would result in high noise being delivered to the receiving circuit; this not only is annoying to the operator or shore subscriber, but also distinctly affects the operating adjustments of the voice frequency equipment. These comprise the main items of apparatus in the radio building.

As shown on the block diagram, figure 2, a 4-wire circuit is used to the Seattle office. In the Seattle office, equipment is provided for combining the transmitting and receiving channels to form a 2-wire circuit capable of being switched over wire circuits of the telephone plant. The equipment, known as "*B*-1 control terminal," includes means for regulating speech volumes; outgoing, so as always to load the ratio transmitter properly; and incoming, so as to give the shore subscriber the best received volume. A voice operated device known as the "vodas" provides means for suppressing echoes and singing. This device is essentially the same in principle and in its operation as those used in intercontinental radio telephone service which have been described in detail in previous publications. In addition to the foregoing units, apparatus for monitoring and testing is provided.

The 2-wire circuit is terminated in the Seattle toll switchboard where it appears as any other long distance circuit. Since the harbor station is arranged for remote control operation, equipment is provided so that the transmitter is turned on automatically when the operator inserts a plug in the "harbor circuit" jack.

Operation

As already noted, the land radio transmitter and receiver at Point Edwards is operated remotely from Seattle, a distance of about 15 miles, where the licensed radio operators assigned to operate the station are located. The transmitter is monitored continuously by means of an auxiliary radio receiver in Seattle tuned to the transmitter frequency. In addition, the 2-way portion of the voice frequency circuit is monitored by means of an amplifier and loud speaker bridged across the circuit through a high impedance coil. This, of course, indicates to the attendant the general status of each connection as to transmission in both directions. Monitoring by means of a headset is also available and usually is resorted to when conditions require close attention to the adjustment of the apparatus to insure a satisfactory connection.

When a call originates on land, the toll operator connects the land line from the shore subscriber to the radio circuit, designated "harbor," by means of a regular toll cord circuit. This operation, which requires the insertion of a plug in the jack of the radio circuit, automatically starts the transmitter at Point Edwards. It also indicates to the radio attendant, by means of an alarm, that a connection is being made and that his attention is required to ascertain whether any adjustments under his control are necessary for proper operation of the circuit. The switchboard operator then rings with a 1,000 cycle signal which registers as an attention call to all ships that have their receivers operated. The particular vessel to which a connection is to be made is called by name and station letter. This ship then starts its transmitter and reports, and the 2 way connection is established.

On calls originating from a ship, the boat's transmitter is energized and its carrier operates the "codan" circuit associated with the land station receiver. An auxiliary circuit actuated by the "codan" functions to signal the Seattle long distance operator by means of the regular toll line lamp signal. It also signals the radio attendant to stand by in the manner just described. The switchboard operator in responding to the signal inserts the answering plug of a cord circuit in the "harbor" jack which energizes the land transmitter. Two way telephone contact then is established with the ship and from this point on, the regular traffic operating procedure is followed in connecting the ship with the desired telephone station.

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Regulation Beyond the Distribution Substation

Nonuniform load growth, which sometimes results in excessive voltage drops in various parts of an electric power distribution system, caused engineers to consider extending the installation of voltage regulating devices to portions of the system beyond the station. As a result, several supplementary devices have been developed for use in distribution circuits between station and load. These devices and their applications are discussed in this paper.

By
P. E. BENNER
ASSOCIATE A.I.E.E.

General Electric Co.,
Schenectady, N. Y.

THE PROVED economy of using induction regulators together with proper feeder design to compensate for rather than eliminate voltage drop in an electric power distribution system has led to a consideration of extending this principle by installing devices to compensate for or reduce voltage drops in certain individual parts of a feeder in the load area. Experimental installations have been made and have proved so successful that considerable interest has been created in the various types of devices involved. This paper presents a review of the fundamental considerations applying to voltage drop and regulation in distribution systems and a discussion of the factors involved in the economic application of the various supplementary devices, together with a brief mention of the developments that made possible the production of small capacity regulators at reasonable cost.

Regulation and Voltage Drop

Regulation, which is one of the 2 fundamental measures of electric service, is defined as the ratio of the difference between no load and full load voltage to normal voltage. The amount of voltage regulation and the limit of permissible voltage variations have been specified by the public service commissions of many states. In 20 states these limits for cities having populations of more than 2,500 vary from plus or minus 3 per cent to plus or minus 6 per cent and average approximately plus $4^3/_4$ per cent to minus $4^1/_2$ per cent for the lighting period. In discussing certain specific examples in this paper, limits of plus or minus 4 per cent are assumed.

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If the substation bus voltage be constant, the regulation of a distributed load consisting of individual customers is determined by the voltage drop from the substation bus to the farthest customer, whereas the regulation of a distributed load on a regulated feeder is determined only by the drop from the nearest to the farthest customer in the load area, as shown by figure 1. This voltage drop in the load area, which determines the regulation, consists of primary, distribution transformer, and secondary drops.

The primary drop may be considered as being divided into 2 parts—3 phase and single phase. For reasons of loss and regulation, 3 phase circuits are desirable for large loads where such loads are balanced and where the full benefit of the 3 phase circuit can be obtained. Assuming equal distances, wire sizes, and conductor spacings, the drop resulting from 3 single-phase 2,400-volt loads wye-connected on a 4,160-volt 3-phase 4-wire circuit is just $^1/_6$ the drop resulting from the same 3 single-phase 2,400-volt loads all connected to the same 2,400-volt single-phase circuit. Ordinarily the circuits constituting the final subdivision of the primary system are loaded so lightly and have such a small voltage drop that 3 phase construction is uneconomical. Also, in the usual types of urban layouts, these circuits serve only a few transformers and so an effective 3 phase balance is not possible. The small voltage drop in a typical single phase lateral circuit, as they conventionally are called, is indicated by the fact that a single-phase 2,400-volt lateral circuit consisting of number 6 (B. & S. gauge) copper conductor and having a 10-kva 0.95-power factor load taken off every 750 feet has a drop of only 1.12 per cent in 3,000 feet. The drops in lateral circuits are maintained at low values when a uniform increase in load occurs by breaking them up with additional 3 phase branches.

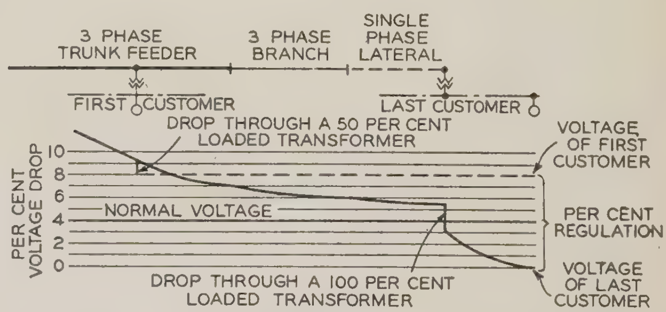

Fig. 1. Distribution feeder regulation

On a regulated feeder, the voltage drop between the first and last customers determines the regulation for the area considered

For instance, doubling the number of 3 phase branches with the corresponding halving of the lengths of the lateral circuits will decrease the voltage drops in the lateral circuits to $^1/_4$ of the original values. The drops in the 3 phase branches and in the 3 phase trunk feeder comprise the rest and usually the major part of the primary voltage drop. The general shape

of the load area determines the proportioning of the 3 phase drop between the trunk feeder and the 3 phase branches.

The average voltage drop in distribution transformers can be compensated for so the only way distribution transformers affect regulation is in the variation of their individual voltage drops from the average. If distribution transformers be applied so that their loads when installed are 50 per cent of rating and when removed 100 per cent of rating, the voltage drops through average sized (15 kva) transformers will vary between approximately 1.25 and 2.50 per cent or 1.25 per cent. This same variation would occur to increase the regulation if transformers were loaded from 75 to 125 per cent or from 100 to 150 per cent. Obviously the variation could be reduced by narrowing the loading limits.

The secondary voltage drop depends on the sizes and lengths of secondary circuits. For ordinary overhead construction, numerous studies have pointed consistently to the economy of controlling this drop in average residential areas by varying the length of secondary circuit rather than by changing the size of conductor. The following example will serve to illustrate this point: A number 1/0 conductor would be required to make a 50 per cent reduction in the voltage drop resulting from a 0.95 power factor current in a secondary circuit of number 4 wire; considering investment alone, if the additional investment required for the larger conductor were applied to decreasing the average secondary circuit length from 500 to 250 feet by doubling the number and decreasing the size of distribution transformers from 15 to $7^1/_2$ kva, the drop would be reduced 75 per cent.

As shown by figure 1 the regulation specified determines the sum total of the primary, transformer, and secondary voltage drops. It is possible by careful economic analysis to proportion correctly the total drop between these various parts. For example, figure 2 shows the rate at which the total

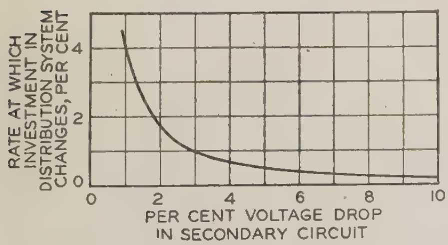

Fig. 2. Effect of secondary voltage drop on distribution system investment

This curve applies to a system in which the investment in distribution transformers and secondary copper is 23 per cent of the total investment in distribution facilities, excluding the substation, when the secondary drop is 3 per cent

investment in distribution facilities changes at each value of secondary voltage drop. Referring to this curve, it may be seen that the total investment changes at the rate of 1 per cent per per cent change in secondary drop when the secondary drop is 3 per cent and at the rate of 0.7 per cent when the secondary drop is 4 per cent. Therefore, if the secondary voltage drop be increased from 3 to 4 per cent, the total investment in distribution facilities will decrease 0.8 per cent (average rate between 3 and 4 per cent secondary drops). This particular curve applies to an average urban distribution system in which the maximum loading of distribution transformers is

This curve applies to the same system as figure 2. When the primary voltage drop is $3^1/_2$ per cent, the investment in 2,400/4,160 volt primary copper is 9 per cent of the total investment in distribution facilities

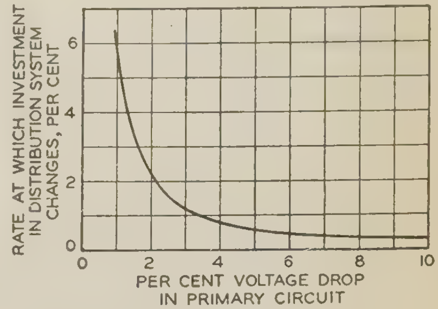

Fig. 3. Effect of primary voltage drop on distribution system investment

from 100 to 150 per cent of their rated capacities and the investment in distribution transformers and secondary circuit copper is 23 per cent of the total investment in distribution facilities from the substation to and including the customers' meters. Figure 3 shows the rate at which the total investment in distribution facilities changes at each value of primary voltage drop in the same hypothetical system. The investment in primary circuit copper in this particular 2,400/4,160 volt primary system is about 9 per cent of the total investment in distribution facilities, not including the substation. Having plotted these curves (figures 2 and 3) the proportioning of the voltage drops in primary and secondary circuits is obviously a matter of determining the primary and secondary drops at which the rates of change of the total investment are equal. For instance, if the total voltage drop in the primary and secondary circuits be $6^1/_2$ per cent, 3 per cent should be allocated to the secondary circuit and $3^1/_2$ per cent to the primary circuit, because the rate at which the total investment in distribution facilities changes is the same (1 per cent) in each case.

Need for Supplementary Regulating Devices

Having thus reviewed the fundamental considerations applying to voltage drop and regulation for ordinary conditions of load density and growth, the extraordinary conditions or exceptions to the rule will be studied. Unfortunately load does not develop over every area as uniformly as might be desired to make economic a generally uniform expansion of primary distribution facilities. This is particularly true in "fringe" areas which only partly are built up. Usually there is a tendency in such areas for certain streets to build up more rapidly than others in the immediate vicinity, which makes the load rather spotty. The primary lateral circuits supplying these streets become loaded and cannot be broken up economically if this requires running in a long 3 phase branch to relieve only 1 or 2 lateral circuits. Several conditions of this nature are indi-

cated in figure 4. The voltage of the last customer served by the 2,400-volt single-phase lateral circuit AB is 6 per cent below the rated voltage, or 2 per cent below the allowable minus 4 per cent. The voltage drop in the lateral circuit itself is $2^1/_2$ per cent. The voltage of the last customer could be brought within the allowable lower limit by making the lateral circuit 3 phase at a cost of at least $250. This expedient, however, makes no provision for future load growth, and it would be of benefit for perhaps only a year or 2 until the construction of a 3 phase branch from C to B was necessary. The other possible alternatives are: (1) the immediate construction of a 3-phase 4-wire branch from C to B, and (2) the installation of a supplementary regulating device at A.

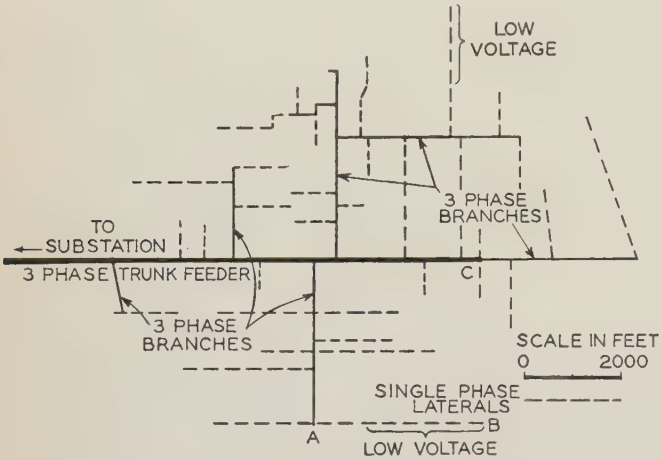

Fig. 4. Urban feeder having several overloaded single phase branches

The low voltage condition on lateral AB can be relieved economically by installing a branch feeder step regulator at A

Allowing for the reduction in losses, the yearly carrying charges on a new 3 phase branch would amount to at least $200, whereas the carrying charges on a suitable branch feeder step regulator would be only about $100; the latter would make possible a saving of approximately $100 a year until a more uniform development of load made the construction of the 3 phase branch desirable. The installation of this regulator would result in a considerable improvement in voltage, in addition to the yearly saving mentioned, because the line drop compensator would make it possible to hold an average voltage several per cent higher than would be obtained even by the construction of a new 3 phase branch. An even larger yearly saving (approximately $150) could be obtained by installing a single-step booster. As this device is not equipped with a line drop compensator and, in this case, would change the voltage in a single 5 per cent step, it would not be possible to hold as uniform a voltage as with the step voltage regulator.

These savings would not have been possible several years ago, because it is only very recently that new developments in tap changing mechanism and control have made the construction of a small capacity regulator feasible from the standpoint of cost. Probably the most important factor in reducing the cost of the tap changing mechanism in the step regulator is the thyrite by-pass shown in the diagram, figure 5, which permits the omission of the heavy and bulky preventive reactor and allows the use of a single movable contact arm. ("Thyrite" is a trade name of the General Electric Company and is used to designate a resistance material that is practically nonconductive at voltages lower than a certain predetermined value.) The oscillogram reproduced in figure 6 shows how the thyrite by-pass carries the load current for $1^1/_2$ cycles when the movable contact is between the stationary contacts during a tap change.

In the single-step booster, an appreciable saving was made possible by taking advantage of the fact that it was a one-step device and substituting a simple resonant relay[1] for the customary contact making voltmeter. The basis of this relay is a nonlinear circuit consisting of a resistor, a reactor, and a capacitor connected in series, with an auxiliary relay coil connected across the capacitor. The nonlinear characteristics of the circuit permit the pickup and drop-out of the auxiliary relay to be adjusted accurately within very close limits.

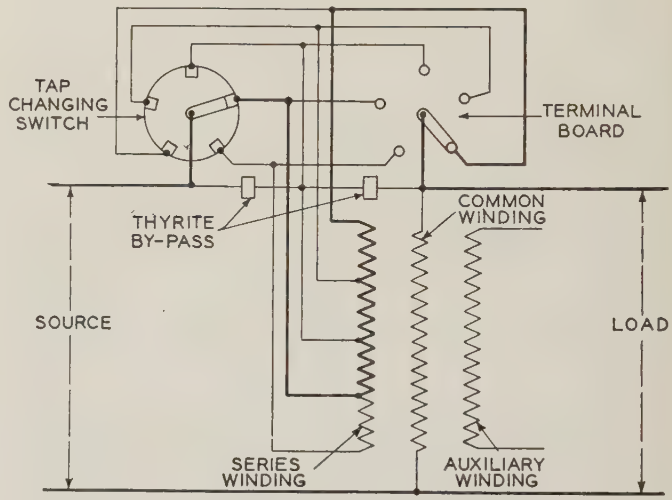

Fig. 5. Schematic diagram of a branch feeder step regulator

The use of the thyrite by-pass greatly increases the simplicity of the tap changing mechanism

The prevalence of lateral circuits having excessive voltage drops is shown by table I, which lists data for actual single-phase, 2,300-volt branch circuits taken from circuit maps of 4 different operating companies. In calculating the per cent voltage drop, it was assumed that the distribution transformers were 50 per cent loaded.

In some instances, the economy anticipated from the construction of large capacity feeders (number 3/0 or 4/0 conductor) has resulted in the use of circuits with current ratings too high for the load density of the area served. This naturally results in feeders that are too long and have too high a voltage drop in the load area. When loads were

1. For all numbered references see list at end of paper.

increasing steadily, it was customary to gamble on the future and take care of excessive voltage drops in 3 phase circuits by running in new feeders, or, if feeder positions were not available, by building new substations. Sometimes the expected load growth has not materialized[2] and uneconomical underloading of feeders and substations has resulted. When a condition of this type exists and the feeder load is limited by regulation rather than by its capacity, the careful consideration of supplementary regulators is recommended. The loading of a feeder with a uniformly distributed load can be increased 50 per cent by installing a bank of supplementary regulators to compensate for the 3 phase drop in the load area. When compared with the alternative of running in a new feeder, the regulator installation would only have to show an advantage in yearly carrying charges over 50 per cent of those for a new feeder.

The proper location of such a bank of regulators is where the trunk feeder drop is $^1/_2$ of its maximum value in the load area. On a feeder having a uniformly distributed load, the location would be $^1/_3$ of the distance into the load area. The current at this point would be $^2/_3$ of its total value and so a regulator rating equal to the present value of the feeder load current would provide for the 50 per cent increased loading that such an installation would make possible. The maximum compensation possible is equal to the voltage drop in the trunk feeder in the load area, unless a special construction such as a back feed is used. An idea of the amount of this voltage drop may be obtained from figure 1.

Conditions most favorable to an installation of this type is a feeder with 2 distinct load centers, but with negligible load between. Consider, for example, a 4,800-volt delta-connected circuit feeding through one small community to another 4 miles distant. Assuming a 6 or 7 per cent voltage drop between the towns, it obviously would be necessary to use a feed back or its equivalent to maintain a reasonable voltage at each of the towns. It is estimated that the cost of 2 miles of circuit for a feed back would be at least 50 per cent more than the cost of 2 4,800-volt branch feeder induction regulators connected open delta. The induction type of regulator would be especially desirable for such an application because of its reliability, low maintenance requirement, and instantaneous response.

Table I—Voltage Drops in Typical Single-Phase 2,300-Volt 2-Wire Lateral Circuits of 4 Typical Distribution Systems

System	Length of Circuit, Feet	Wire Size, B. & S. Gauge	Transformer Kva	Assumed Load, Amperes	Per Cent Voltage Drop
A	3,950	4 & 6	357	77.5	4.8
	2,600	6	188	41.0	2.0
	3,300	4	340	74.0	3.1
	6,400	4	385	83.5	6.6
B	2,100	6	200	43.5	1.7
	3,700	6	165	35.9	2.5
	3,700	1/0	196	42.5	1.0
	2,000	6	107	23.5	0.9
C	10,900	6	96	20.9	4.3
	10,500	6	114	24.8	4.8
	3,240	4	159	34.6	1.4
	5,100	4	130	28.3	1.8
D	5,000	6	95	20.5	1.9
	6,150	6	218	47.5	5.4
	6,600	6	167	36.5	4.5
	4,100	6	230	50.0	3.8

Instantaneous Regulation Causing Light Flicker

So far this discussion has been confined to regulation caused by steady loads. Of increasing importance is instantaneous voltage drop which causes light flicker. The majority of lamp flicker complaints involve only one particular secondary circuit and individually may not amount to very much. In the aggregate, however, they may be rather serious.

The 2 general methods of reducing the instantaneous drop in secondary circuits are: first, by design, and second, by the addition of supplementary devices. In regard to design, there is, of course, the possibility of reinforcing the circuit either by using a larger conductor, or by interspacing transformers, or both. For a 12 inch spacing the resistance and reactance of a number 1/0 copper conductor are approximately the same; therefore, as the size of wire approaches and exceeds that size, the benefit obtained by increasing wire size decreases rapidly because, although the resistance decreases, the reactance remains approximately the same, and for low power factor current the largest part of the voltage drop in the heavier conductors is due to the circuit reactance. Some thought has been given also to decreasing the conductor spacing. The larger the conductor the more effective this becomes. For instance, decreasing the spacing from 12 inches to 1 inch will reduce the voltage drop caused by a 0.50 power factor current 21.5 per cent in a number 4 conductor, and 38.5 per cent in a number 2/0 conductor.

Assuming the same total transformer capacity, a slight improvement may be obtained by decreasing the length of secondary circuit. Specifically decreasing the size of transformers from 15 to 10 kva with a resultant decrease in spacing from 1,000 feet to 666 feet decreases the voltage drop caused by the 0.50 power factor starting current of a motor in number 2, 4, and 6 secondary conductors by ap-

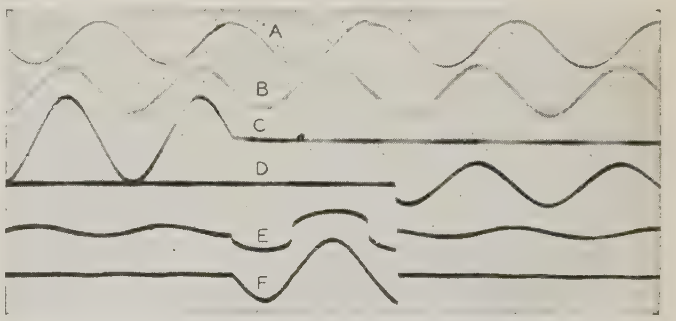

Fig. 6. Current and voltage relations in regulator of figure 5 during a tap change

A. Load voltage
B. Load current in line
C. Current in high tap
D. Current in low tap
E. Thyrite switching by-pass voltage
F. Current in thyrite by-pass

During the tap change the load current flows through the thyrite by-pass

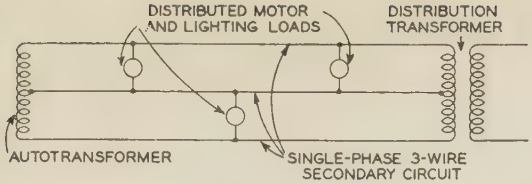

Fig. 7. Connection of autotransformer in secondary circuit for reducing instantaneous voltage fluctuations

The best location of the autotransformer is at the end of the secondary circuit if the motor loads are distributed

proximately 19.5, 22.5, and 25 per cent, respectively. The larger the transformer, the larger will be the reduction experienced. For instance, decreasing the transformer size from 25 kva to a hypothetical $16^2/_3$ kva with the resultant decrease in spacing from 1,000 feet to 666 feet will decrease the voltage drop caused by the 0.50 power factor current in a number 2 secondary conductor by approximately 24.5 per cent.

The problem of reducing instantaneous voltage drop causing light flicker has given added impetus to the practice of banking or interconnecting transformer secondary circuits. It can readily be seen that the interconnection of similar secondary circuits will reduce the maximum voltage drop (at the midpoint between transformers) by 50 per cent.

The Secondary Autotransformer

Instantaneous voltage fluctuations on secondary circuits usually are caused by the starting of motors connected from line to neutral. Obviously if such motors were for line-to-line connection the voltage drop would be only $^1/_4$ of the drop for the line-to-neutral connection for the same starting kilovolt-amperes (neglecting voltage drop in transformer). A large part of this possible improvement can be obtained by installing an autotransformer in the secondary circuit,[3] as shown by figure 7. Its function is to transform the motor starting current at line-to-neutral voltage to line-to-line voltage and thus cause it to be transmitted at line-to-line voltage rather than at line-to-neutral voltage, with the consequent 75 per cent reduction in voltage drop. On a circuit having distributed motor load, the best location for the autotransformer is at the end of the circuit, although the maximum reduction in voltage drop caused by any particular motor would be obtained by placing the autotransformer at that motor. The curves of figure 8 show the effectiveness of autotransformer installations on secondary circuits and indicate that for most installations the optimum size of autotransformer of the design on which the curves are based is 3 kva. The installed cost of a 3 kva autotransformer is about the same as the cost of extending a single phase primary circuit one pole span where such an extension requires setting a new pole. The application of autotransformers has been found to be very attractive for temporarily relieving bad voltage situations until the extension of primary facilities is desirable. In one case of underground primary construction, saving the carrying charges of a primary extension for only a few months more than paid for the complete installation of an autotransformer.

Primary Series Capacitor

Ordinarily the voltage fluctuations reflected in the primary circuit are not sufficiently large to cause lamp flicker. However, when such a situation does occur, it is quite serious, first, because of the large number of customers affected, and second, because of the large expenditure usually required to correct it.

Occasionally, normal allowable starting currents of motors near the end of a long primary circuit cause objectionable voltage fluctuations. In several situations of this kind, it was possible to bring about the necessary reduction in instantaneous voltage drop by neutralizing the inductive reactance of the circuit by installing a series capacitor. In one of these situations the series capacitor installation cost only about $^1/_3$ as much as the cheapest alternative.[4]

By overneutralizing the inductive reactance it is possible to obtain a reduction in instantaneous voltage drop caused by current of a low power factor in a circuit, the impedance of which is predominantly resistive. Considerable caution must be used in this connection, however, because the amount of correction obtained depends largely on the power factor of the current.

For economic reasons it is desirable that the capacitive reactance (X_c) and correspondingly the capacitor voltage drop be as high as possible. This is because capacitive reactance is inversely proportional to the capacitance ($X_c = 1/[2\pi fc]$) and the capacitance has a direct bearing on capacitor cost.

In general, the successful application of the series capacitor depends on 4 factors:

1. Instantaneous regulation required on account of light flicker.
2. Line reactance a large part of the total impedance.
3. Compensation not restricted by loads tapped off at close intervals along the feeder.
4. The rating of the capacitor economically feasible.

The enthusiasm for the various supplementary regulating devices shown by engineers who have

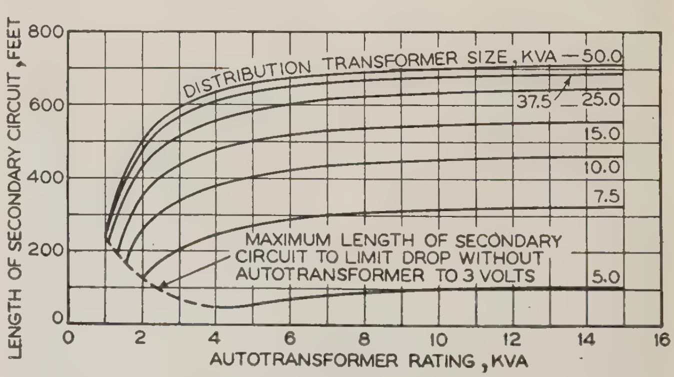

Fig. 8. Autotransformer capacity required to reduce secondary voltage dip to 3 volts

The 3 volt dip, which includes the voltage drop in the distribution transformer, is caused by the 25-ampere 0.50-power factor starting current of a $^1/_3$ horsepower motor. These curves apply to a secondary circuit of number 4 copper wire having an average conductor spacing of 12 inches

applied them successfully is excellent evidence that such devices have a place in distribution system design. Believing that it would be of real benefit to the industry, this paper has attempted to bring about a more general appreciation of how, in certain instances, applications of supplementary devices make it possible to save carrying charges by deferring major system additions, to eliminate line rebuilding in which the original investment in copper largely is lost, and to supplement existing facilities as conditions require so as to approach the ideal of making system additions on the basis of existing rather than anticipated loads.

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Lightning Currents in Field and Laboratory

A review of available data on the magnitude and effects of lightning stroke currents, supplemented by laboratory experiments to check these effects, is presented herewith. Maximum currents of 150,000 to 200,000 amperes having durations of from 40 to 100 microseconds are indicated.

By
P. L. BELLASCHI
MEMBER A.I.E.E.

Westinghouse Elec. and Manufacturing Company, Sharon, Pa.

LIGHTNING stroke currents were produced in the laboratory[1] early in 1933. Since then, physical effects associated with natural lightning have been compared directly with similar results obtained in the laboratory. This has been an effective method in determining the currents involved in the lightning stroke.

The more common field experiences with lightning current phenomena hereto recorded by or reported to the author have been associated largely with the following effects: (1) fusion of conductors, (2) crushing of parallel conductors and of tubes, (3)

1. For all numbered references see list at end of paper.

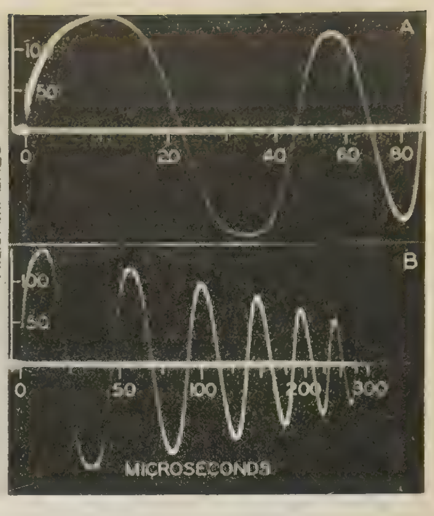

Fig. 1. Oscillograms of 140,000 ampere discharge from lightning stroke current generator

Period ≌ 45 microseconds. Duration to half crest value = 190 microseconds

surface burning of conductors, (4) explosive and shattering effects, (5) magnetic and magnetizing effects, (6) characteristics of lightning arc proper, and (7) miscellaneous effects. Accordingly, the laboratory data on lightning currents presented here are confined to these corresponding field experiences. Furthermore, because of the continually accumulating field information the present paper will be limited largely to factual data. However, the author has made use in part of analyses already available to compare the field experiences with the laboratory measurements. Rapid progress has been made lately toward a quantitative understanding of lightning phenomena. The mechanism of the lightning stroke formation has been revealed most effectively by means of the "rapid" camera.[2] New and improved methods for determining lightning currents have been applied in the field. After a trial period both here[3] and abroad[4] the magnetic link has been found particularly suitable to measure lightning stroke currents on transmission lines.[5,6,7] Another device found adapted to measure lightning currents consists simply of 2 metal discs separated with thin paper insulation;[8] this device has been employed to measure the lightning currents in the ground wires of lightning arresters. By these 2 methods some valuable data on lightning currents have been procured in the past 2 or 3 years. These data are summarized here briefly for the purpose of comparison with the data recorded by the method described in this paper.

For practical purposes the various methods now available for recording the characteristics of lightning stroke currents may be sufficient; but from a scientific standpoint it is suggested and urged that eventually direct measurements of the lightning stroke with the cathode ray oscillograph be made as a final

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The author acknowledges the assistance received from many sources in securing part of the field data recorded in this paper, and particularly of the following: W. J. Humphreys (U. S. Weather Bureau) and D. D. Clarke (Kansas City Power and Light Company) who made available, respectively, the crushed lightning rod and the crushed parallel conductors; A. H. Schirmer (Bell Telephone Laboratories) who submitted extensive data on the fusion of conductors; J. K. Hodnette (Westinghouse Electric and Manufacturing Company) who secured valuable field data in conjunction with his development of the deion gap for distribution transformers; and W. L. Teague (Westinghouse Electric and Manufacturing Company) who assisted in the laboratory investigation and analysis of data.

confirmation. In all events, field experience undoubtedly will continue to remain a most valuable source of information, well worth recording and analyzing. In fact, field experience alone can be the ultimate confirmation of the adequacy of protective equipment and devices employed in electric circuits and with apparatus, and also of other schemes and devices, such as the lightning rod, used to safeguard property, animal stock, and human life.

Fusion of Conductors

The current of a single lightning discharge that would fuse a conductor is given by the expression[1]

$$I^2T = (kA)^2 \tag{1}$$

where

A = area of conductor in square millimeters
I = crest value of current in amperes
T = duration of current in microseconds, measured from start to the half-crest value on the tail of the wave
k = a numerical constant which is a function of the conductor material and of the wave form of the current

For the exponential current $i = I\epsilon^{-0.693\,t/T}$, the constant k equals 320,000 for copper and 200,000 for aluminum. From limited tests on bronze and steel wires having cross-sectional areas between 1.0 and 3.0 square millimeters, k = 200,000 and 220,000, respectively. For a multiple stroke of current discharges I_1, I_2, I_3, etc., of corresponding durations T_1, T_2, T_3, etc., the sum of the products I^2T would be added in equation 1, provided all the heat generated in the conductor is retained during the total duration of the stroke.

Field investigations with the cathode ray oscillograph show a duration of the waves produced on transmission lines by lightning of from 15 to 100 microseconds. Measurements by B. F. J. Schonland (South Africa) of the duration of luminosity in the main channel and of the time required for the main discharge to progress from earth to cloud would indicate an average duration of the discharge in the order of 50 microseconds. His measurements also reveal that the wave form is characterized by a sustained peak on the crest which endures a fractional part of the duration of the wave. More remains to be known of the wave form and duration of the lightning stroke current, but a duration of 40 to 100 microseconds on the basis of an equivalent exponential wave seems reasonable to assume at the present.

Another consideration pertains to the repetitive nature of the stroke. Some strokes are single discharges; others are multiple discharges, only a few involving more than 4. The first discharge is apparently the most intense and severe, while the successive ones appear to be reduced in intensity. It is important, however, to note that actually 80 per cent of the strokes to lines comprise a single discharge,[4,9] while the remaining 20 per cent are multiple discharges rarely exceeding 4. Field observations seem to indicate that multiple discharges of lightning actually may strike the ground at places apart. All these considerations will be given proper weight in deducing the lightning stroke currents from the fusion of conductors.

Hundreds of instances virtually are known where 2.05 square millimeter bronze conductors (used in telephone circuits) have been fused by lightning. Hundreds of 2.08 square millimeter (number 14) copper conductors (employed on antennas, for house wiring, for grounding, etc.) also have been reported to have been fused by lightning. An instance has been recorded where lightning vaporized a 3.34 square millimeter (number 12) copper conductor.[10] Another instance is known where a 5.25 square millimeter (number 10) conductor was beaded at the point of contact with the stroke, but not fused.[1] Experiments conducted by E. C. Starr (Oregon State College, Corvallis) have shown that the current in a direct lightning stroke can be expected to fuse 2.08 square millimeter copper wires and smaller, but that larger conductors ordinarily will conduct the current successfully to ground.

Several instances are known where overhead copper telephone wires of 5.50 and 8.32 square millimeter cross section were parted at the point where lightning struck, presumably because the lightning discharge caused the wire to lose its tensile strength at the point hit. One source relates unconfirmed reports of copper conductors up to and including

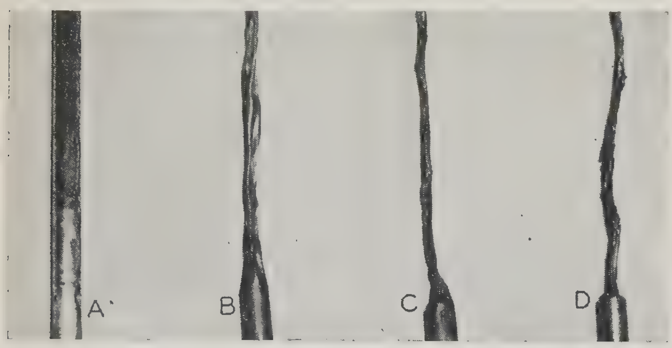
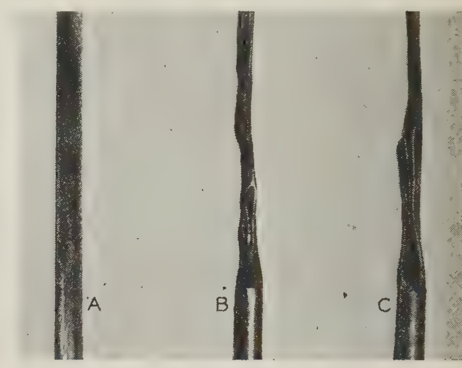


Fig. 2. Copper tubes crushed by lightning currents in laboratory (tubes had 14.3 millimeter inside diameter and 0.254 millimeter wall thickness)

A—Original tube
B—After single discharge of 140,000 amperes
C—After 2 successive discharges of 140,000 amperes
D—After 3 successive discharges of 140,000 amperes



A—Original tube
B—After 3 successive discharges of 140,000 amperes
C—After 4 successive discharges of 135,000 amperes

Fig. 3. Copper tubes crushed by lightning currents in laboratory (tubes had 14.3 millimeter inside diameter and 0.406 millimeter wall thickness)

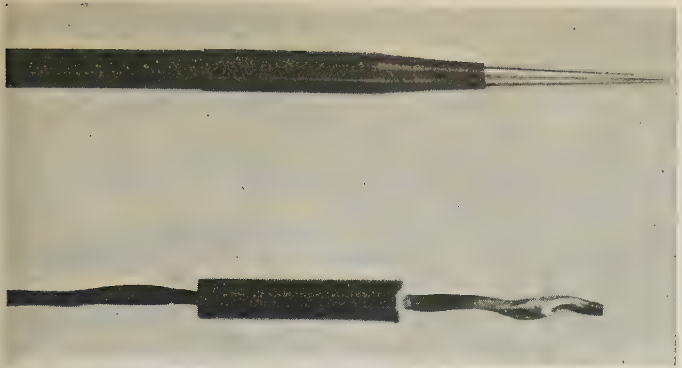


Fig. 4. Lightning rod crushed in the field by lightning stroke discharge[16] (rod had a 14.65 millimeter inside diameter and 0.675 millimeter wall thickness; original rod is shown at top)

13.45 square millimeters that apparently have been fused, while another source states that in no instance was 13.45 square millimeter copper wire fused. From a reliable source it is known where several thousands of 20.9 square millimeter steel ground wires have been installed now for a few years. These ground wires protect a corresponding number of wood poles, which otherwise would frequently be shattered. To date none of these ground wires have been found fused. It is also worth noting that about 30 square millimeter copper and 60 square millimeter steel conductors are prescribed for lightning rods[11, 12, 13, 14], as experience has proved these conductors are fully adequate to discharge the lightning strokes.

From the numerically predominant instances of 2.05 square millimeter bronze and 2.08 square millimeter copper conductors that have been fused by lightning, the present conclusions are justified. On the basis established that the bulk of these fusions were produced by a single discharge or possibly by a heavy single discharge followed by a weak discharge, then from equation 1 and on the basis of 40 microsecond duration the great majority of the severe lightning strokes would involve a current in the order of 100,000 amperes. On the basis of 100 microsecond duration, the current would be in the order of 65,000 amperes. On the assumption of a single discharge fusing the 3.34 square millimeter copper conductor, the lightning current would be 170,000 and 110,000 amperes for durations of 40 and 100 microseconds, respectively. The limited number of reports where copper conductors of cross sections greater than 5.00 square millimeters were fused by lightning are unconfirmed in part or dubious and partly contradicted by reports from other sources. A few investigators have observed copper conductors of 30 square millimeters and larger that have been heated by the lightning stroke to high temperatures, near to the point of fusion[15,16]. There are indications in such instances (also discussed later) pointing to the probability of multiple strokes as having fused the larger conductors.

From the data on the fusion of conductors, hereto reported, one concludes that the probability of lightning stroke currents exceeding considerably 100,000 amperes is rare, though there are indications from these data that lightning currents may attain 150,000 to 200,000 amperes at the most.

Crushing of Conductors

When 2 conductors d centimeters apart each carry a current of I amperes for an average duration of T seconds, each conductor acquires per centimeter length a momentum

$$mv = FT = \frac{2I^2T}{100d} \text{ dyne-seconds} \tag{2}$$

where

F = attractive force in dynes
m = mass of each conductor per centimeter length, ingrams
v = velocity of each conductor at end of time T

The force action of lightning currents producing the crushing of parallel conductors and tubes is accounted for quantitatively by this fundamental relation.

In one case reported by W. J. Humphreys,[16] figure 4, a hollow copper tube having an inside diameter of 14.65 millimeters and a wall thickness of 0.675 millimeters (32.5 square millimeter section) was crushed by lightning. From the incipient fusion indicated in several places it would seem that this tube was raised to a high temperature. On the assumption of a 100,000 ampere discharge, a force of 400 pounds per square inch of tube surface would be calculated.

Experiment shows that in addition to the current magnitude, the duration and repetitive discharges of the stroke also would influence the crushing of conductors. Copper tubes having an inside diameter of 14.3 millimeters and wall thicknesses 0.127, 0.254, and 0.406 millimeters, each securely brazed along the square-joint seam, were tested. Figure 1 shows typical oscillograms of the currents discharged through the tubes. The 0.127 millimeter tube collapsed partially on a single 80,000 ampere discharge; it was crushed on a single 95,000 ampere discharge; a single 135,000 ampere discharge completely crumpled the tube. The thicker tubes collapsed and

Fig. 5. Parallel conductors crushed together by: (left) direct stroke of lightning in field;[17] and (right) 4 successive discharges of 140,000 amperes each in the laboratory

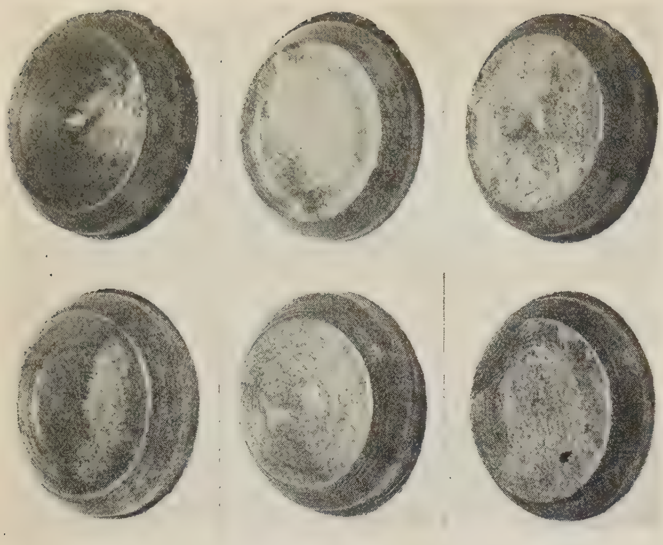


Fig. 6. Lightning currents recorded in field (bottom group) compared with those produced in laboratory (top group) from the extent and amount of surface burning appearing on the face of the deionizing gap plugs

Left—Discharge of about 25,000 amperes
Center—Discharge of about 50,000 amperes
Right—Discharge of about 100,000 amperes

were crushed on repeated discharges. These repeated discharges were applied about one minute apart, the time required to charge the lightning current generator[23] fully, and therefore some of the heat produced was dissipated between discharges. The amount of crushing produced by 1 to 4 successive discharges, each of 140,000 amperes, can be seen in figures 2 and 3. On the basis of a single discharge, it would appear that lightning strokes unusually severe, in either the amount of current or duration, or both, would be required to crush the rather thick tubes reported; apparently from the laboratory tests, lightning currents in the order of and greater than 200,000 amperes would be required. It seems likely, from this and other evidence, that the lightning strokes that produced crushing of the tubes reported were in the nature of multiple strokes, each discharge being of relatively more moderate current amplitude than otherwise would be required to account for the crushing from a single discharge.

D. D. Clarke has reported and analyzed a very interesting instance where 2 parallel, 8.32 square millimeter copper conductors were crushed together by lightning.[17] Each conductor originally was insulated with triple-braid weatherproof covering and spaced from the other about 10 to 15 centimeters. The lightning stroke found its way down a tree and then to the 2 service wires. It stripped them completely of the insulation, crushing them in semblance into one round conductor. There was no evidence of excessive heating of the conductors, but the lightning stroke was nevertheless severe, judging from all the damage. Accordingly, 2 conductors identical to those employed in service were properly arranged and spaced for test. It was found that the first discharge at 140,000 amperes (figure 1) would strip the rather tough (new) insulation, while the successive discharges would crush the 2 conductors together more and more until after the fourth discharge they resembled closely in appearance the field specimen, as can be seen from figure 5.

From equation 1 a 100,000 ampere discharge of 100 microsecond average duration produces a force of about 350 pounds on each conductor per foot of length. Each conductor assumes a speed of 22 feet per second. With double this current the force and speed are each quadrupled. From data on multiple lightning discharges, the interval between discharges is relatively large so that the 2 conductors would come together before the second discharge took place. The impact energy required to have crushed the 2 conductors observed in the field can be accounted for with no great difficulty on the basis of a severe multiple lightning stroke of about 4 or 5 discharges. Theoretically, a single discharge of rather high current likewise would produce the crushing.

From the field data on the crushing of tubes and conductors reported hereto, it appears that a single lightning discharge would have to attain a current magnitude of 200,000 amperes or more in order to produce such effects. What is more probable is that multiple discharges of more moderate currents have occurred; several of these discharges readily could have produced the crushing.

Surface Burning of Conductors

Field records of lightning strokes near and at distribution transformers protected with deionizing gaps have furnished valuable data. The electrodes of the deionizing gaps discharging the lightning current are marked with a surface figure which, when compared with similar figures on deionizing gaps tested in the laboratory with known lightning cur-

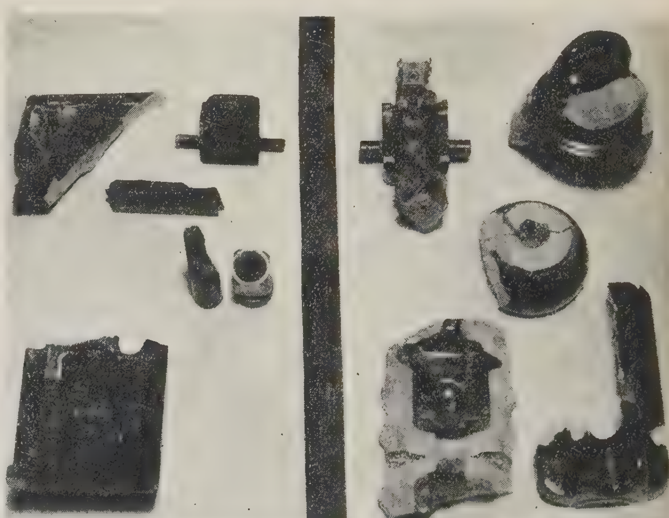


Fig. 7. Shattering effects produced by lightning currents

Right—Shattering of line and guy-wire insulators, fuse cutouts, etc., produced by lightning stroke discharge to distribution line
Left—Similar effects produced with known lightning currents in the laboratory

rents, enables evaluating the lightning current discharged through the deionizing gaps in service. Such a comparison of lightning currents recorded in the field and in the laboratory may be seen in figure 6.

A record of lightning strokes near and at distribution transformers during 1932–33, mounted in suburban or rural areas, is shown by curve *A* in figure 8. A direct stroke at the terminals of a transformer recorded in 1934 indicated a current somewhat greater than 100,000 amperes. The dash-dot extension to 150,000 amperes is intended to represent the maximum current in a stroke recorded to date from this field experience; however, this maximum value does not preclude the rare possibility of 200,000 amperes.

Explosive and Shattering Effects

Direct strokes at distribution transformers also have shattered line and guy-wire insulators, fuse cutouts, and similar apparatus. Such results were produced by the severe stroke cited in the preceding section of this paper, can be seen in figure 7. As the figure shows, similar effects can be produced in the laboratory, in which event the lightning currents required are known.

Lightning strokes to guy wires have blasted the rock, cement, etc., in which the wire was embedded. Shattering of wood poles and trees is a familiar occurrence. Metal pipes have been cracked and even broken open by lightning. The parts of shattered bodies have been projected distances of 100 feet and more. Large holes have been dug a few feet deep into the ground. It is not possible to compare all these and other field experiences with direct laboratory tests, but the forces involved will become apparent from some of the laboratory results.

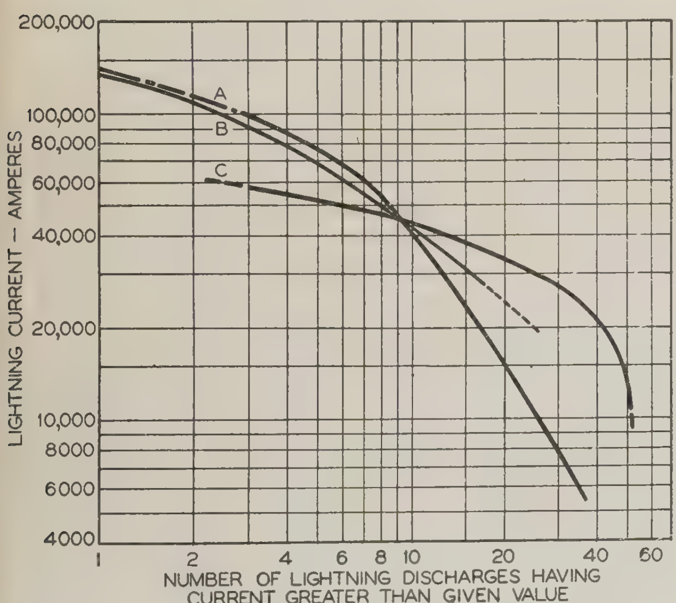


Fig. 8. Comparison of magnitude of lightning currents as ascertained from 3 different sources

A—Direct or near-direct strokes of lightning at distribution transformers during 1932–33, mounted in suburban or rural areas. Transformer years = 4,000

B—Direct strokes of lightning to transmission lines[7]

C—Direct strokes of lightning to transmission lines[4]

Fig. 9. Appearance of lightning stroke discharge of 140,000 amperes produced in laboratory (see oscillograms in figure 1 for duration)

Laboratory tests with fiber tubes indicate that a current discharge, such as in figure 1 when confined to a bore having a diameter substantially less than 2 centimeters gives rise to internal pressures in the order of 10,000 to 20,000 pounds per square inch and perhaps more. These experiments on fiber tubes indicate that when the lightning arc is restricted to a section substantially less than 2 centimeters in diameter high pressures are developed which have a bearing on the dimension of the "core" section of the lightning stroke channel, as will be discussed later. In short, from a consideration of the explosive forces that can be produced by lightning currents in the laboratory, it should not be difficult to account for the destructive effects encountered from natural lightning.

Magnetizing Effect

The practical method now commonly used to measure the lightning currents discharged through the steel towers of transmission lines depends simply on the magnetization of magnetic links and their ability to retain the magnetization produced. Each link consists of a bundle of small magnetic elements so that the magnetization produced is proportional to the amplitude of the current, independently of the wave form. With modern facilities for calibrating these links, apparently dependable data on lightning currents have become available in the past few years.

Many investigators have reported the magnitudes of lightning currents discharged through the towers.[3,5,6] Sporn and Gross also have calculated the currents of the lightning stroke from the currents recorded in the towers.[7] Likewise Grünewald was able to estimate the lightning stroke currents[4] from the currents recorded in the towers and in the ground wires. These data on lightning stroke currents are plotted in figure 8 (curves *B* and *C*). It can be seen that the magnitude of the lightning stroke currents reported to date, as determined from the

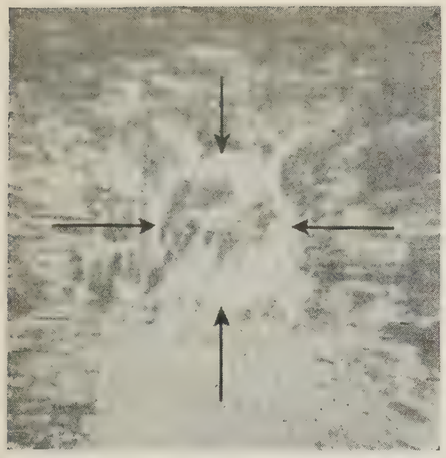


Fig. 10. Surface burning produced by 140,000 ampere discharge in laboratory which indicates the "core" diameter of the lightning stroke to be 1.5 centimeters

various methods discussed, are substantially of the same order.

Characteristics of Lightning Arc

The lightning discharge in the laboratory is similar to the lightning stoke in nature. The light produced by the laboratory discharge is intensely brilliant and blinding. The sound produced by the discharge, although the arc is only about 4 feet long, is uncomfortable and even painful to the ear. If one were taken unaware by a laboratory discharge occurring a few feet away, the deafening noise and the blinding light quite likely would produce a stunning effect, much the same as natural lightning does. The diameter of the 140,000 ampere discharge of figure 1, as recorded by the camera at 10 feet from the arc, is about 10 centimeters (figure 9). With the camera removed to a greater distance from the arc, the diameter on the photograph appears still larger (about 20 or 25 centimeters).

The true diameter of the "core" of the arc becomes evident only from certain experimental observations. The fiber tube experiments mentioned previously would indicate the "core" to be about 1 to 2 centimeters in diameter. Another experiment comprised of discharging the arc with a fine copper wire (0.08 millimeter in diameter) to the center of a thick polished copper plate (0.5 by 12 by 12 centimeters). A very small hole was bored at the center of the plate just large enough to carry the fine wire straight through. The 140,000 ampere discharge (figure 1) would produce a uniformly burned surface in the form of a circle about 1.5 centimeters in diameter, as shown in figure 10. The amount of surface burning diminished with a decrease in the discharge current. These experimental data thus demonstrate that the "core" of the lightning stroke channel is in the order of 1 to 2 centimeters in diameter, perhaps 1.5 centimeters representing a severe stroke. From recent theoretical analysis[18] of the characteristics of the stroke channel the deductions conform substantially to the laboratory observations.

Summary

1. From the available substantial data on the fusion of conductors, lightning stroke currents infrequently exceed considerably 100,000 amperes (on the basis of 40 to 100 microsecond duration to half crest value on the tail of the wave). These data indicate that lightning currents may attain maximum values of 150,000 to 200,000 amperes. Similarly, limited instances of severe crushing of tubes and conductors would indicate that on the basis of a single stroke the current would have to attain an amplitude of 200,000 amperes and somewhat more to produce such effects. It is more probable that multiple strokes, consisting of several successive discharges, each discharge involving a relatively smaller current, account for the fusion of the heavier conductors and for the few instances of severe crushing of conductors recorded.

2. Lightning current distribution curves (figure 8) established from lightning data on transmission and distribution circuits and based upon different methods of measurement indicate a substantially similar trend. The current amplitudes from these sources range from about 10,000 amperes to a maximum in the order of 150,000 amperes. These current values are in general agreement with those deduced from the data on the fusion and crushing of conductors.

3. From a comparison of the pressures giving rise to the explosive and shattering effects observed in the field and in the laboratory, it is confirmed still further that the lightning currents generated in the laboratory simulate those in lightning strokes. Pressures are developed from the restricting or confining of the lightning current arc, which are of the order of 10,000 to 20,000 pounds per square inch and perhaps more.

4. Physical characteristics of the lightning arc (light, sound, current density, etc.) have been investigated in the laboratory, establishing also in this respect that the field and laboratory phenomena are essentially of the same nature. From tests of lightning current discharges confined in fiber tubes, and from other tests of surface burning of polished metal plates, the "core" of the lightning stroke channel has been established experimentally as having a diameter of 1 to 2 centimeters, approximately 1.5 centimeter diameter representing a severe stroke.

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Recent Research in Radio Communication

A review of the literature describing research investigations in the field of radio communication, published in the United States and other countries during the past year and more, indicates the progress being made in this field. For each of the 5 principal classifications into which radio communication research is found to be divided, a summary of recent progress is included as part of this article, and a bibliography totaling 104 items gives reference to the principal articles in these 5 divisions.

By
FERDINAND HAMBURGER, JR.
MEMBER A.I.E.E.

The Johns Hopkins University, Baltimore, Md.

A REVIEW of research in radio communication during the past year indicates that research efforts in this field may be divided broadly into 5 general classifications as follows: (1) studies of electromagnetic wave propagation; (2) ultra-short-wave investigations; (3) research in television; (4) studies of the properties of antennas; and (5) investigations of high fidelity. The order of listing indicates the extent of interest of the particular classification as evidenced by the quantity of material published. Each of these divisions of research will be summarized briefly and a bibliography appended.

Especially prepared for Electrical Engineering under the auspices of the A.I.E.E. committee on research; submitted for publication April 3, 1935, subsequently brought up to date as of July 1, 1935.

1. All numbered references in each section refer to bibliography under the corresponding section.

Studies of Electromagnetic Wave Propagation

The research investigations in this field can be subdivided into 3 parts: (1) direct investigation of the properties of the ionosphere (Kennelly-Heaviside layer); (2) studies of propagation between fixed points on the earth's surface; and (3) development of apparatus and methods to improve the conditions of study of wave propagation.

The attack on the ionosphere is universal. Investigations of its properties have been reported from such widely separated points as Washington, D. C.; Australia; Moormansk, U.S.S.R.; Peru; Calcutta; Bangalore, South India; Sydney, Nova Scotia; and others. The principal method of attack has in most cases been the pulse method of Breit and Tuve[1] with modifications, or the frequency change method of Appleton and Barnett.[2]

The general results of these investigations may be briefly summarized. A number of layers have been evident; the major daytime layers are the E layer at 100–120 kilometers virtual height, the F_1 layer at about 180 kilometers virtual height and the F_2 layer at about 240 kilometers virtual height. The relative electron densities of these layers have been measured. The critical frequencies of the various layers (the lowest frequency at which a wave passes through the layer) have also been measured together with their diurnal and seasonal variations. Typical of the practical potential use of the information now being gathered and aside from the importance of the data as improving our knowledge of the fundamental properties of the ionosphere is the indicated correlation between the results of the ionosphere studies and actual transmission studies as mentioned by Kirby, Berkner, and Stuart.[3] Their observations indicate a relation between the highest critical frequency of the F_2 layer and the highest frequency at which waves can be received over great distances. They found that the maximum frequency at which waves are reflected from the F_2 layer was very much less in summer than in winter. This checks with the results of Burrows[4] who showed that during trans-Atlantic transmission in 1928–29 the highest frequency at which waves could be transmitted across the Atlantic was 22 megacycles in summer and 28 megacycles in winter. As the information concerning the ionosphere continues to accumulate from all over the world, it is certain that knowledge of the earth's ionized atmospheric regions will be considerably enhanced and with it the ability to provide satisfactory radio communication at all times. The bibliography on this subject which follows makes no pretentions to completeness, but it is hoped that the more important studies on this subject, reported during the past year, have been listed. The paper by Kirby, Berkner, and Stuart[3] gives an historical summary of the published studies on the ionosphere together with the report of the U.S. Bureau of Standards observations from September 1930 to April 1933.

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Ultra-Short-Wave Investigations

In this branch of radio research the principal line of attack has been the design and development of satisfactory oscillators for frequencies above 100 megacycles. As is well known, oscillators of the conventional negative grid type are, in general, unsatisfactory for frequencies much above this limit and resource has been had to positive grid and magnetron oscillators. During the year one of the developments has been the design of tubes of small dimensions that can be used successfully as negative grid oscillators above 100 megacycles. Typical of this development is the so-called "acorn" tube described by Thompson and Rose,[1] and by Salzberg.[2] Various types of positive grid oscillators using special triodes or other tubes have been described by Kamio,[3] Thompson and Zottu,[4] Okabe,[5] Hamburger,[6] and others. Studies of special types of magnetron oscillators have been reported by deFassi and Salom[7]; Slutzkin; Leljakow; Kopilowitsch; Wyschiniski and Usikow;[8] and Wolff, Linder, and Braden.[9]

The most recent publication on this topic is the paper of Fay and Samuel[10] describing 2 special triodes for negative grid oscillations and 2 special triodes for positive grid oscillations. For the 2 negative grid oscillators they report the following: one tube capable of producing 0.9 and 8.5 watts at 700 and 200 megacycles with an efficiency of 3 per cent and 29 per cent, respectively; the other produces 12 and 55 watts at 100 and 300 megacycles with an efficiency of 17 per cent and 50 per cent. For the 2 negative grid oscillators they show for one tube a power output of 4.5 and 8 watts at 500 and 600 megacycles with 6 per cent and 5 per cent efficiency, and for the other tube an output of 0.4 and 5.5 watts at 2,000 and 700 megacycles and an efficiency of about 1 per cent.

A number of other investigations have been reported dealing with other phases of ultra-short-wave radio communications, as can be seen from the bibliography. The papers of Hollman,[11] Kelly and Samuel,[12] and that of Scheibe[13] give summaries of the various phases of the subject of ultra-short-wave communication.

Following are the principal references in this field:

1. Vacuum Tubes of Small Dimensions for Use at Extremely High Frequencies, B. J. Thompson and G. M. Rose, Jr. *I.R.E. Proc.*, v. 21, Dec. 1933, p. 1707.

2. Design and Use of Acorn Tubes for Ultra-High Frequencies, B. Salzberg. *Electronics*, v. 7, Sept. 1934, p. 282.

3. Triode for Generating Electron Oscillations, K. Kamio. *Radio Res.* (Japan), report 3, Dec. 1933, p. 229.

4. An Electron Oscillator With Plane Electrodes, B. J. Thompson. and P. P. Zottu. *I.R.E. Proc.*, v. 22, Dec. 1934, p. 1376.

5. On the Production of Ultra-Short-Wave Oscillations With Cold Cathode Discharge Tubes, K. Okabe. *I.R.E. Proc.*, v. 21, Nov. 1933, p. 1593.

6. Electron Oscillations With a Triple Grid Tube, F. Hamburger, Jr. *I.R.E. Proc.*, v. 22, June 1934, p. 79.

7. Magnetron as Generator of Ultra-Short Waves, G. deFassi and G. Salom. *Alta. Frequenza*, v. 3, Aug. 1934, p. 396.

8. Output and Efficiency of Efficiency of Magnetron Oscillators, A. A. Slutzkin, P. P. Leljakow, E. A. Kopilowitsch, I. A. Wyschinski, and A. J. Usikow. *Phys. Zeits. d. Sowjetunion*, v. 5, 1934, p. 887–901.

9. Transmission and Reception of Centimeter Waves, I. Wolff, E. G. Linder, and R. A. Braden. *I.R.E. Proc.*, v. 23, Jan. 1935, p. 11.

10. Vacuum Tubes for Generating Frequencies Above One Hundred Megacycles, C. E. Fay and A. L. Samuel. *I.R.E. Proc.*, v. 23, Mar. 1935, p. 199.

11. Generation and Application of Ultra-Short Waves, H. E. Hollman. *Hoch. u. Elek.*, v. 44, Aug. 1934, p. 37.

12. Vacuum Tubes as High Frequency Oscillators, M. J. Kelly and A. L. Samuel. Elec. Engg. (A.I.E.E. Trans.), v. 53, Nov. 1934, p. 1504.

13. Short and Ultra-Short Waves, A. Scheibe. *Phys. Zeits.* v. 35, Mar. 1, 1934, p. 206.

14. Electron Oscillations, J. Muller. *Hoch. u. Elek.*, v. 43, June 1934, p. 195.

15. Electron Oscillations Without Tuned Circuits, W. H. Moore. *I.R.E. Proc.*, v. 22, Aug. 1934, p. 1021.

16. Phase Angle of Vacuum Tube Transconductance at Very High Frequencies, F. B. Llewellyn. *I.R.E. Proc.*, v. 22, Aug. 1934, p. 947.

17. Note on Vacuum Tube Electronics at Ultra-High Frequencies, F. B. Llewellyn. *I.R.E. Proc.*, v. 23, Feb. 1935, p. 112.

18. Vacuum Tube Electronics at High-Frequencies, F. B. Llewellyn. *I.R.E. Proc.*, v. 21, Nov. 1933, p. 1532.

19. New Type of Ultra-Short-Wave Oscillator, S. Ohtaka. I.E.E. (Japan), v. 54, Jan. 1934, p. 1.

20. Increasing the Output of Ultra-Short-Wave Oscillators, S. Ohtaka. I.E.E. (Japan), v. 54, Feb. 1934, p. 87.

21. Resonant Lines in Radio Circuits, F. E. Terman. Elec. Engg. (A.I.E.E. Trans.), v. 53, July 1934, p. 1046.

22. Note on an Ionized Gas Modulator for Short Radio Waves, E. G. Linder and I. Wolff. *I.R.E. Proc.*, v. 22, June 1934, p. 791.

23. Valve Efficiency and Frequency Measurement in Ultra-Short-Wave Region, R. Beck. *Hoch. u. Elek.*, v. 43, June 1934, p. 199.

24. Seventy-Five Centimeter Radio Communication Tests, W. D. Hershberger. *I.R.E. Proc.*, v. 22, July 1934, p. 870.

25. Theory of Ultra-Short-Wave Oscillators, E. W. B. Gill. *Phil. Mag.*, v. 18, Nov. 1934, p. 832.

26. Generation and Utilization of Ultra-Short-Waves in Radio Communication, F. A. Kolster. *I.R.E. Proc.*, v. 22, Dec. 1934, p. 1335.

27. Ultra-Short Waves in Urban Territory, C. R. Burrows, L. E. Hunt, and A. Decino. Elec. Engg. (A.I.E.E. Trans.), v. 54, Jan. 1935, p. 115.

28. Practical Communication on the 224-Mc. Band, Ross A. Hull. *Q.S.T.*, v. 18, Nov. 1934, p. 8.

29. Theory of Ultra-Short-Wave Generators, E. W. B. Gill. *Phil. Mag.*, v. 18, Nov. 1934, p. 832.

30. Use of Magnetic Fields for the Production of Ultra-Short-Waves, M. Ponte. *Onde Elec.*, v. 13, Dec. 1934, p. 493.

31. Micro-Waves, N. Carrara. *Alta Frequenza*, v. 3, Dec. 1934, p. 661.

32. Generation of Electric Waves Below One Meter in Wave Length, K. W. Wagner and H. E. Hollmann. *E. N. T.*, v. 11, Dec. 1934, p. 418.

Research in Television

Television research has brought about remarkable developments. The principal investigators have departed from the old mechanical scanning method and its inherent difficulties and have introduced electronic scanning. A complete description of an experimental television system using electronic scanning at the transmitter and a cathode ray tube at the receiver is given by Engstrom[1] and his associates, featuring the iconoscope of Zworykin.[2]

A second television system also using electronic scanning is described by Farnsworth.[3] Both of these systems have reached the point in development where satisfactory images can be received using as subjects for transmission outdoor scenes as well as studio performances and motion picture film. The theory of scanning has received further treatment by Maloff[4] and by Mertz and Gray.[5]

Another field of investigation with application to television has been the development of special wire transmission lines to accommodate the wide frequency bands needed for television. Schelkunoff[6,7] and Espenschied and Strieby[8] have reported along these lines.

Following are the principal references in this field:

1. Symposium, An Experimental Television System. *I.R.E. Proc.*, v. 22, Nov. 1934, p. 1241, 1246, 1266, 1286.

2. The Iconoscope—A Modern Version of the Electric Eye, V. K. Zworykin. *I.R.E. Proc.*, v. 22, Jan. 1934, p. 16.

3. Television by Electron Scanning, P. T. Farnsworth. Frank. Inst. *Jl.* v. 218, Oct. 1934, p. 411.

4. Problems of Cathode Ray Television, I. G. Maloff. *Electronis*, v. 7, Jan. 1934, p. 10.

5. Theory of Scanning, P. Mertz and F. Gray. *Bell Sys. Tech. Jl.*, v. 13, July 1934, p. 464.

6. Coaxial Communication Transmission Lines, S. A. Schelkunoff. Elec. Engg. (A.I.E.E. Trans.), v. 53, Dec. 1934, p. 1592.

7. The Electromagnetic Theory of Coaxial Transmission Lines and Cylindrical Shields, S. A. Schelkunoff. *Bell. Sys. Tech. Jl.*, v. 13, Oct. 1934, p. 532.

8. Wide Band Transmission Over Coaxial Lines, Lloyd Espenschied and M. E. Strieby. Elec. Engg. (A.I.E.E. Trans.), v. 53, Oct. 1934, p. 1371.

9. Television by Electronic Methods, A. H. Brolly. Elec. Engg., (A.I.E.E. Trans.), v. 53, Aug. 1934, p. 1153.

10. Construction of High-Vacuum Braun Tubes for Television and Measurement Purposes, M. v. Ardene. *Hock. u. Elek.*, v. 44, Nov. 1934, p. 166.

11. Principles and Problems of Television, E. Hudec. *Naturwiss*, v. 22, Nov. 9, 1934, p. 749.

12. Symposium, An Experimental Television System. *I.R.E. Proc.*, v. 21, Dec. 1933, p. 1631, 1652, 1655, 1674, 1692.

13. Survey of Present Systems—Television. *Electronics*, v. 7, Oct. 1934, p. 300.

14. An Electron Multiplier. *Electronics*, v. 7, Aug. 1934, p. 242.

Studies of the Properties of Antennas

Further studies of the properties of antennas have been conducted particularly with a view of controlling the radiation pattern of the antenna. Several methods for accomplishing this have been reported—the tuning method of Nickle, Dome, and Brown[1] and a somewhat similar method by Reinartz.[2]

Investigations have also been carried out on methods of maintaining the directivity of antenna arrays, a most important problem in aircraft beacon work, for example. Two methods have been reported—one by Roder,[3] and the other by Kear.[4]

Other investigations include those of the properties of special types of antennas, such as the rectangular short-wave frame aerial of Palmer and Taylor[5] and the horizontal rhombic antennas of Bruce, Beck, and Lowry.[6] A most interesting investigation of the possibility of the use of high frequency models in antenna studies has been made by Brown and King.[7]

Following are the principal references in this field:

1. Control of Radiating Properties of Antennas, C. A. Nickle, R. B. Dome, and W. W. Brown. *I.R.E. Proc.*, v. 22, Dec. 1934, p. 1362.

2. A New Antenna System for Operating Control of Radiation, J. L. Reinartz. *Q.S.T.*, v. 19, Feb. 1935, p. 9.

3. Elimination of Phase Shifts Between The Currents in Two Antennas, Hans Roder. *I.R.E. Proc.*, v. 22, Mar. 1934, p. 374.

4. Maintaining the Directivity of Antenna Arrays, F. G. Kear. *I.R.E. Proc.*, v. 22, July 1934, p. 847.

5. Rectangular Short Wave Frame Aerials for Reception and Transmission, L. S. Palmer and D. Taylor. *I.R.E. Proc.*, v. 22, Jan. 1934, p. 93.

6. Horizontal Rhombic Antennas, E. Bruce, A. C. Beck, and L. R. Lowry. *I. R. E. Proc.*, v. 23, Jan. 1935, p. 24.

7. High-Frequency Models in Antenna Investigations, G. H. Brown and Ronold King. *I.R.E. Proc.*, v. 22, April 1934, p. 457.

8. Tower Antennas, E. A. Laport. *Electronics*, v. 7, Aug. 1934, p. 238.

Investigations of High Fidelity

Considerable interest has been evidenced in the improvement of the quality and fidelity of broadcast transmissions. Several critical studies of this subject have been published, among them the reports of Ballantine[1] and Goldsmith.[2] In addition, several papers on the improvement of the component parts of a complete transmitter have appeared such as the papers of Olson[3] and Seabert.[4] Much remains to be accomplished in this field.

Following are the principal references in this field:

1. High Quality Radio Broadcast Transmission and Reception, Stuart Ballantine. *I.R.E. Proc.*, v. 22, May 1934, p. 564.

2. Conditions Necessary for an Increase in Usable Receiver Fidelity, Alfred N. Goldsmith. *I.R.E., Proc.*, v. 22, Jan. 1934, p. 9.

3. A New Cone Loud Speaker for High Fidelity Sound Reproduction, Harry F. Olson. *I.R.E. Proc.*, v. 22, Jan. 1934, p. 33.

4. Electrodynamic Speaker Design Considerations, J. D. Seabert. *I.R.E., Proc.*, v. 22, June 1934, p. 738.

5. High Fidelity Broadcast Transmitter Performance, E. A. Laport. *Electronics*, v. 7, May 1934, p. 144.

6. Some Notes on Adjacent Channel Interference, I. J. Kaar. *I.R.E. Proc.*, v. 22, Mar. 1934, p. 295.

Corona Losses at 230 Kv With One Conductor Grounded

Tests have been made to determine the increase in corona losses on a high voltage transmission line, due to the grounding of one of the conductors. The corona losses under this condition of operation, which may occur on a transmission system not having the neutral solidly grounded, are shown to be considerably increased over the more usual operation with all 3 conductors at the same voltage. This corona loss may increase the in-phase component of current, with a consequent effect on the operation of Petersen coils. The conductors of the line used in these tests were hollow copper conductors composed of interlocking segments.

By
JOSEPH S. CARROLL, ASSOCIATE A.I.E.E. — Stanford University, Calif.

DONALD M. SIMMONS, FELLOW A.I.E.E. — General Cable Corp., New York, N. Y.

THE increase in corona losses due to the grounding of one conductor of a high voltage transmission line having the neutral not solidly grounded, may affect the operation of other equipment, such as Petersen coils. A Petersen coil, or other form of reactor, has often been placed between the neutral and ground. The purpose is, of course, to neutralize the charging current by the lagging current flowing through the grounding reactor, if an intermittent ground is placed on a conductor, thereby reducing the current to a low value so that the arc will extinguish itself. For theoretically perfect operation, the 2 currents should be equal and should have no in-phase component. As a practical matter, satisfactory operation has been obtained without complete theoretical perfection of conditions, but cases have been reported where unduly high corona losses have caused such a shift in the phase of the charging current as to cause less satisfactory performance.

The authors are not aware of any measured values of corona losses on a transmission line with one phase grounded; corona losses have usually been made with balanced 3 phase voltage. For instance, under normal conditions in a 230 kv line, there would be voltages of 230 kv, respectively between the conductors, and a voltage of 133 kv between each conductor and ground. If one conductor should become grounded (with an ungrounded neutral or a neutral grounded through a reactor) the same voltage will exist as before between conductors, but the voltage to ground of 2 conductors will be 230 kv, with zero voltage to ground on the other conductor. It would be expected that this would change the corona

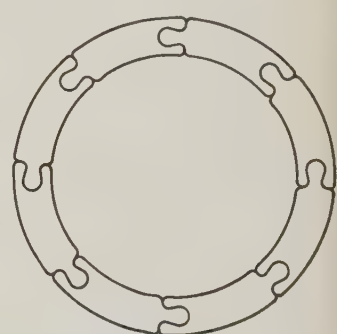

Fig. 1. 1.10 inch, 500,000 circular mil segmental hollow copper conductor

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losses, but the only way to make such a determination is by actual measurements.

The authors, therefore, arranged to make some actual measurements at the Ryan High Voltage Laboratory of Stanford University. The test set-up is described in full in "Corona Losses From Conductors of 1.4 Inch Diameter" by J. S. Carroll, Bradley Cozzens, and T. M. Blakeslee (ELECTRICAL ENGINEERING, December 1933, pages 854–60) except that in this case, the spacing between conductors was reduced to 22 feet.

The cable measured was a hollow conductor composed of interlocking segments having a total cross sectional area of 500,000 circular mils, and with an outside diameter of 1.1 inch. Figure 1 shows the cross section of the cable.

When this conductor was erected initially it was prepared for the test as described in the paper previously referred to; that is, it was thoroughly washed inside and out with gasoline; then washed outside with soap and water, and with clear water. The curves shown in this paper were taken after the cable had weathered for approximately one month, during which time there had been some rain. Except for the weathering, nothing had been done to the cable since the original washing.

To obtain the proper phase relation of voltages, only 2 of the transformers described in the previous work were used. One side of the high voltage winding of each transformer was grounded. The high voltage side of one transformer was connected through the wattmeter to one of the conductors of the test line; the high voltage side of the other transformer was connected through a wattmeter to the second conductor; the third conductor was grounded. The

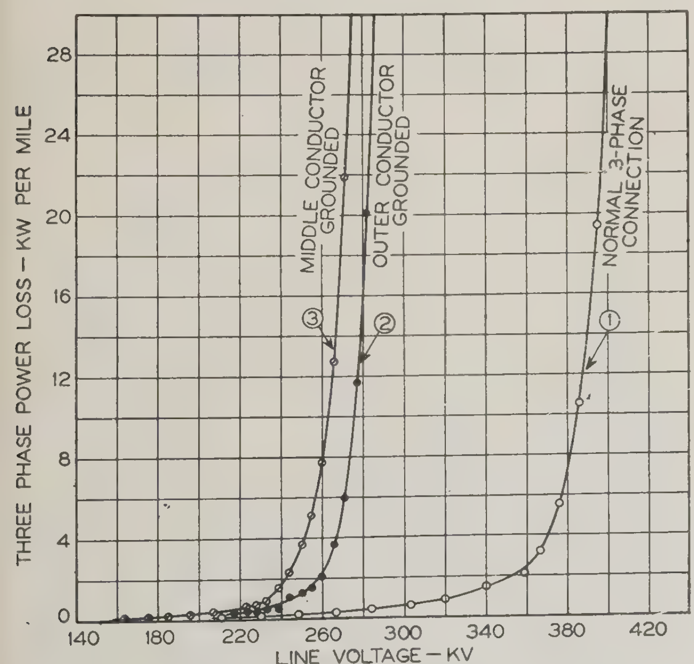

Fig. 2. Three phase corona loss curves for 1.1 inch segmental hollow copper conductor

Curve No.	Date	Condition	Barom. In. Hg.	% Rel. Humid.	Temp. Deg F Air	Temp. Deg F Cable
1	11–28–34	After gasoline, soap and water washing	30.16	46	60.5	68.0
2	12–19–34	After 1.25 in. rain	30.20	62	61.8	70.0
3	12–19–34	After 1.25 in. rain	30.20	60	61.0	68.0

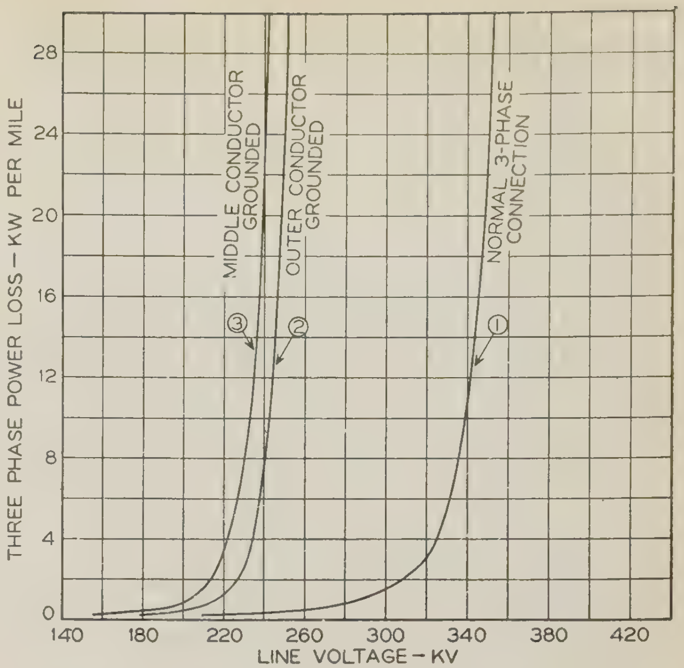

Fig. 3. Three phase corona loss curves for 1.1 inch segmental hollow copper conductor at 4,000 feet elevation

These curves computed from measured values of figure 2

primaries of these transformers were connected to the 3 phase generator in such a manner that the phase angle between the voltage of one of the conductors to ground and the voltage of the other conductor to ground was 60 degrees. This arrangement gave an equivalent 3 phase system with one of the conductors grounded.

Figure 2 shows the results obtained, both when an outer conductor was grounded and when the middle conductor was grounded, and also for normal 3 phase voltage. The increase in loss under the grounded condition is very great, especially with the middle conductor grounded. Since these measurements were made at practically sea level, and since transmission lines often go to much higher levels, it was thought that it might be of interest to compute the values for 4,000 feet elevation. These curves are shown in figure 3, and at this elevation the losses become very significant.

It is realized that in order to draw a definite conclusion in a given case, such measurements should be made for any given size and type of conductor under consideration for a transmission line. These curves will, however, at least give an indication of the order of the magnitude of the change in corona. It should be pointed out also that with this smooth surfaced segmental cable, the losses are very much lower than with a cable with round wires on the surface. The loss curves as shown in this paper are for the 1.1 inch diameter segmental cable only. However, when these data are plotted with other published results reduced to similar conditions, the diameter of an ordinary stranded cable for the same normal loss is found to be approximately 1.3 inches; presumably a similar ratio would hold for the grounded condition.

A New Carrier-Current Coupling Capacitor

By means of coupling capacitors connected to high voltage power transmission lines, high frequency carrier currents in different frequency channels may be transmitted over the power lines for supplementary services such as relaying, control, and communication. A new design of coupling capacitor has been made which, by combining 1, 2, 3, or 4 units in series, may be used on 69, 138, 230, or 287 kv circuits. Capacitors of the latter rating are being used on the Boulder Dam line of the city of Los Angeles.

By
E. D. EBY
MEMBER A.I.E.E.

General Elec. Co.,
Pittsfield, Mass.

THE Boulder Dam power transmission system of the City of Los Angeles (Calif.) bureau of power and light, which employs a higher line voltage than has been used previously in this country, will utilize high frequency carrier-current channels for several distinct purposes; these include relaying, supervisory control of switching stations, telephone communication between stations, and telephone communication with patrolmen's automobiles in the vicinity of the line.

The foregoing factors demanded carrier-current coupling capacitors for connection to the high voltage line, having characteristics considerably superior to any previously considered. Adequate insulation, compactness, light weight, ease of installation, flexibility of mounting, and economy had to be combined with ample capacitance for carrier-current coupling for the several channels and at the same time for obtaining potential for the various relays and instruments.

Adequate insulation and coupling capacitance could have been provided by the use of a series-multiple combination of coupling capacitor units of existing types, but the resulting assembly would have been prohibitive from the standpoint of size and cost. Therefore, the development of an entirely new type was undertaken, as described in this paper.

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Selection of Capacitor Type, Voltage Rating, and Capacitance

Several obvious advantages, and others apparent from detailed studies, favored small series connected units in contrast with a single large unit capacitor for this voltage. Ease and economy of manufacture, simplicity of testing, lighter weight, economy in packing and shipping, and facility of handling and installing were all in support of this conclusion. Replacement of units in case of damage was not overlooked. The application of the small-unit type to lower voltage circuits would be advantageous to both manufacturer and operator.

A survey of existing operating voltages showed the prominence of 69, 138, and 230 kv circuits, suggesting division of the 287 kv capacitor into 4 units, each rated 69 kv. From a review of the 60 cycle and impulse characteristics of apparatus and line insulation for these 4 circuit voltages, it was found that a 69 kv capacitor unit, in series combinations of 2, 3, and 4 units, respectively, would co-ordinate satisfactorily with the insulation requirements of 138, 230, and 287 kv circuits. This was confirmed later by actual tests.

Since these capacitors were intended to serve the double purpose of carrier-current coupling and potential coupling, it was necessary to consider the output demanded by both classes of service. It was desirable to avoid multiple strings of units at the higher voltages. It was found that the carrier-current demand for the 287,500 volt circuit would be provided for by a capacitance of 0.00075 microfarad. Thus, with 4 units in series, the unit capacitance would be 0.003 microfarad. This capacitance would also provide adequate output for potential devices. (This output would be about 150 volt-amperes, which, incidently, would be practically uniform for the several other combinations at their respective circuit voltages.)

Individual Rolls and Assembled Stacks of the Capacitor

The 2-unit 138-kv capacitor is shown in figure 1, and the paper foil stack of the single-unit 69-kv capacitor is shown in figure 2. Alternate layers of paper and aluminum foil are wound on a cylindrical mandrel to form a roll which is subsequently flattened to an approximately square shape. The paper extends beyond the foil sufficiently to provide adequate creepage distance. During winding, 2 tinned copper connectors are placed in contact with each foil, $^1/_4$ of the length from each end, and these are subsequently connected in parallel. Thus the charging current divides between the 2 leads, and the current in each lead divides in 2 when it reaches the foil. Noninductive current flow is obtained, and no current flows along the foil more than $^1/_4$ of its length.

The rolls are assembled into stacks and connected in series. The ends of the stack are connected respectively to the cap and to the base. The connection at the bottom is made permanently at assembly of the rolls upon the base, while connection at the top

is made by a tinned copper braid of sufficient length to permit attachment to the interior of the cap before the latter is assembled to the enclosing porcelain shell.

The base plate of the assembled stack illustrated in figure 2 forms the bottom end of the completed unit, and serves as the foundation for the assembly. The rolls are divided into 4 groups by circular herkolite (molded insulation) separators, and similar plates are placed at the bottom and top of the stack. Clamping of the rolls is accomplished by means of 4 insulating rods passing through holes in the herkolite plates, and located midway of the 4 flat faces of the stack. The bottom ends of the 4 rods are threaded into the base plate and the upper ends are fitted with clamping nuts. Between the separator plates, the insulating rods pass through herkolite tubes which provide exact and equal spacing for each quarter of the stack. A nickel plated steel clamping member at the top of the stack transmits the pressure of the clamping nuts on the upper ends of the rods. Under these nuts, cam-shaped insulating washers are located, which provide a means of centering and locking the upper end of the stack in rigid position inside the shell.

The top clamping plate, which is held in fixed relation to the base of the unit by the 4 clamping rods, is provided with 2 upwardly projecting wings welded to the plate. Through holes in their upper ends a transversely assembled steel rod engages recesses on the interior of the cap. This feature provides an emergency support for the unit in case of accidental breakage of the porcelain shell.

Porcelain Housing and End Castings

The housing consists of a one-piece cylindrical porcelain shell, having a smooth unglazed interior and a deeply petticoated exterior finished in standard chocolate glaze. This porcelain has a wall thickness of $1^1/_8$ inches, except at the ends which are outwardly tapered and roughened for holding the portland cement mortar. The inside diameter of the porcelain shell is $5^1/_4$ inches and its over-all length is $24^1/_2$ inches. The string length arcing distance between clamping rings is $21^3/_4$ inches, and the external creepage distance is 57 inches. The cross-sectional area of the cylindrical body between petticoats is $22^1/_2$ square inches indicating a tensile strength exceeding 60,000 pounds.

Both ends of the porcelain are smoothly ground to fit tightly against the gaskets which form the seal between the porcelain and the machined castings. A grinding tolerance of plus or minus $^1/_4$ inch assures that the finished length of each unit will not depart more than this amount from the average.

To both ends of the porcelain shell there are cemented nickel-plated aluminum alloy clamping rings, each having tapped holes for 8 $^1/_2$ inch galvanized steel cap screws for applying pressure to the gasket. By reason of the tapered ends of the porcelain, the mortar between porcelain and clamping ring is placed under compression as well as shear when clamping pressure is applied. The inner surfaces of clamping rings are deeply grooved to receive mortar.

The cap and base castings are made of special aluminum alloy, developed for this particular application to secure both oil tightness and gas tightness. During the process of manufacture both castings receive several high pressure air tests under water to insure their complete soundness and freedom from porosity. Both of these castings are formed with 4 bolt bosses, drilled on the same bolt circle, by means of which the cap of one unit may be bolted to the base of another to form a rigid axial connection for either base or suspension mounting.

The cap forms an expansion chamber to contain the inert gas which serves as a cushion to prevent excessive pressure in the oil at elevated temperatures. There is but one opening into this gas chamber from the outside, through which the treating and filling is carried on, after which this opening is sealed with a large-headed plug under-cut to contain a gasket which is completely enclosed when compressed. The plug is locked in final position by means of a wire cable and lead seal.

The interior of the unit is filled with mineral oil

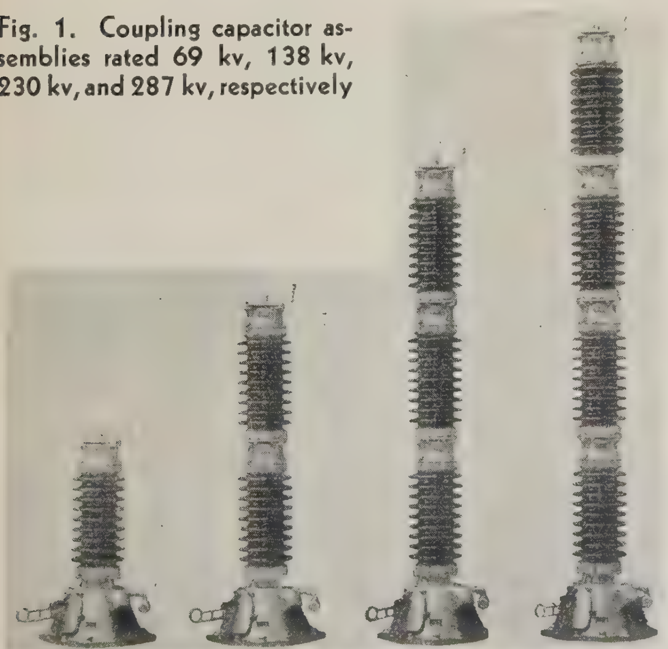
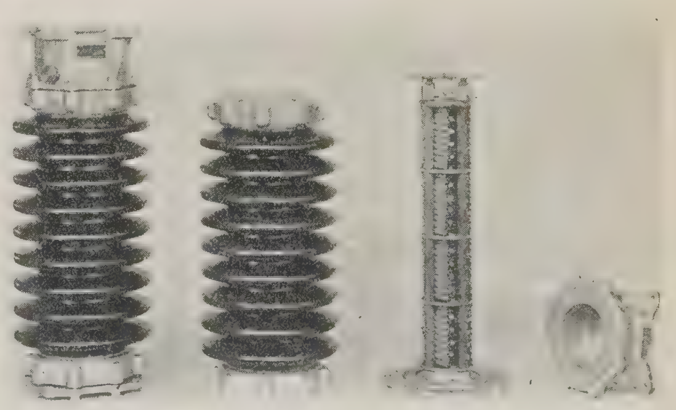


Fig. 1. Coupling capacitor assemblies rated 69 kv, 138 kv, 230 kv, and 287 kv, respectively

Fig. 2. 69 kv capacitor unit and component parts



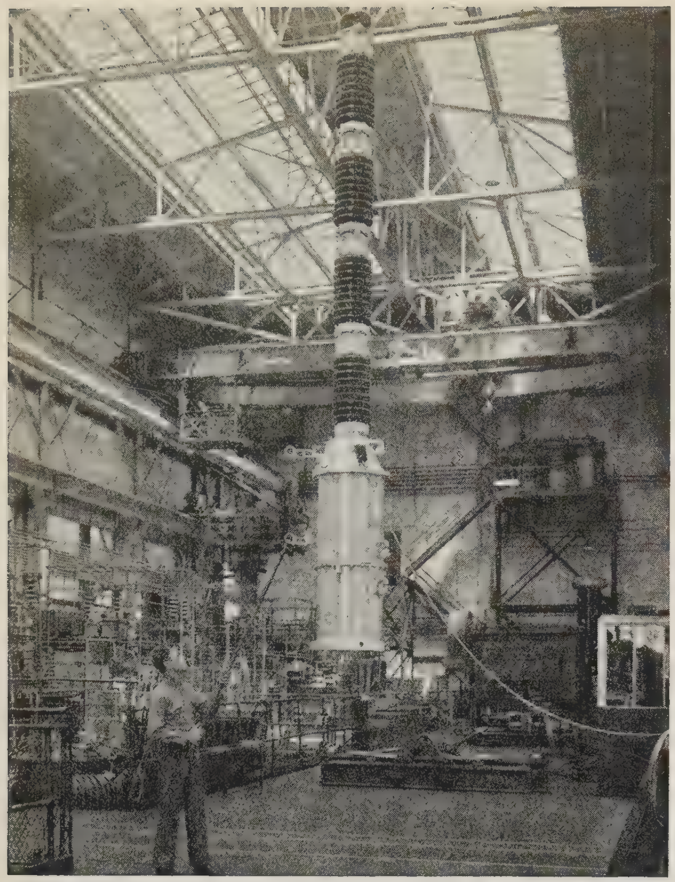


Fig. 3. Coupling capacitor assembly for the Boulder Dam transmission line, rated 287.5 kv, with potential device attached at the bottom

Bell crank operation of the potential device grounding switch is shown

up to the level of the opening in the cap, completely submerging the capacitor element. All gaskets are made of oil resistant weatherproof rubber compound. The gaskets at the ends of the porcelain are set in recesses in the castings and are under definite confinement when compressed. Positive pressure upon these gaskets is maintained by extra-heavy galvanized spring steel washers under the clamping bolt heads, so that no possible flow of the gaskets can open the joints to leakage of oil.

For suspension mounting, a plate with lifting clevis is bolted to the cap of the uppermost unit. The line lead is attached to a terminal lug carried by the suspension plate.

Bottom Unit and Base

The foregoing description applies to the unit designed for use as the middle or top section of a capacitor; of these, 3 are included in the 287,500 volt capacitor, in combination with one unit designed with a different type of base. The latter unit is the lowest of the 4 units in the stack and is built upon a cone-shaped base casting by means of which the capacitor is mounted upon the potential device housing, as shown in figure 3.

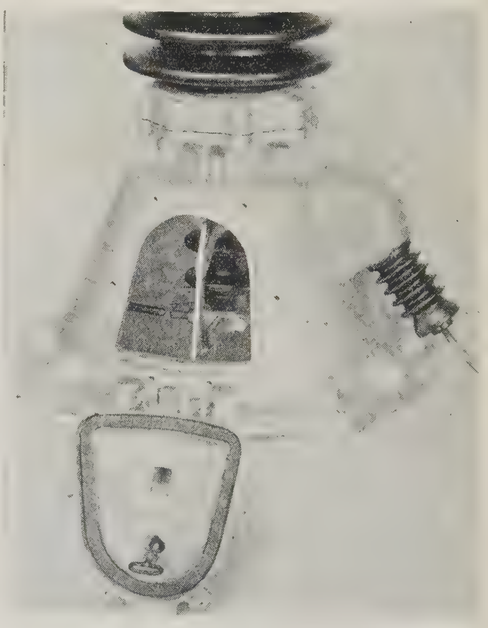
The base casting of the bottom unit is made of the same oil-tight aluminum alloy which forms the base and cap of the middle or top unit. The stack of paper-foil rolls is the same, but rests upon the end of a porcelain bushing, rated 15 kv, which is mounted in the upper end of the conical base, as shown in figure 4. The lead from the lower end of the stack is connected to the conductor rod of the bushing, and is insulated from the grounded base casting.

The bottom end of the bushing in the base carries a terminal block upon which are mounted: (*a*) the connection terminal for the lead to the potential device in the housing below the base; (*b*) one electrode of the protective gap, the other electrode of which is supported from the inside of the base; and (*c*) the receiving clip for the grounding switch which is hinged on a bracket mounted at the bushing clamp. This grounding switch is actuated by a push-rod mounted in the hinged door of the base. This push-rod may be operated through the bell crank mounted on the outside of the door by means of a standard switch hook, without disturbing the door; or the push-rod may be locked in place in the door in such a position that the switch will be closed automatically if the door is opened. The door is bolted to the base, with a cork gasket in the joint to exclude moisture.

As shown in figures 1, 3, and 4, a corrugated porcelain outlet is mounted in one side of the base, for passing the insulated lead to the carrier-current cabinet. This porcelain outlet provides generous creepage surface from this lead to ground and minimizes loss of carrier-current energy through leakage. At another point on the base casting is mounted

Fig. 4. View showing interior of the base of a bottom unit of a coupling capacitor

The grounding switch and protective gap may be seen. Appearance of the base with the door closed is shown in figures 1 and 3



the ventilating breather. For the Boulder Dam installation these breathers are packed with glass wool to exclude dust from the interior without interfering with the free passage of air.

The base is bolted to the flanged upper end of the pontential device housing, with an overhung cork gasket joint. For excluding dust and preventing

injury during handling and shipment, a temporary sealing plate closes the lower end of the base. Four lugs cast on the lower edge of the base provide for mounting upon a foundation when desired.

Assembly, Treatment, and Testing

Assembly is carried on with great care and precision in every detail. All interior parts and surfaces are made scrupulously clean as the assembly operation progresses. When the last bolt has been tightened, the entire unit is subjected to an air pressure test while submerged under water. Not the slightest leak is permitted to pass this inspection. Further assurance of complete tightness is furnished during treatment, when the units must hold a very fine vacuum for many hours.

The vacuum treatment and filling, which are applied to a large number of units at once, involve individual connections to each unit from common manifolds, one for vacuum and one for oil. During the vacuum treatment the units are maintained at oven temperature to insure complete drying of the capacitor paper.

After the specified length of treatment, degasified oil is admitted while vacuum is maintained. The oil enters by gravity until the units are full, after which they are allowed to cool with oil pressure maintained. When the units have reached room temperature they are removed from the oven, the oil level adjusted to its normal position, and the gas expansion chamber filled with nitrogen. The single opening is then sealed, after which the unit is ready for commercial tests.

Every unit receives routine commercial tests, such as measurement of capacitance, measurement of 60 cycle power factor, high potential 60 second

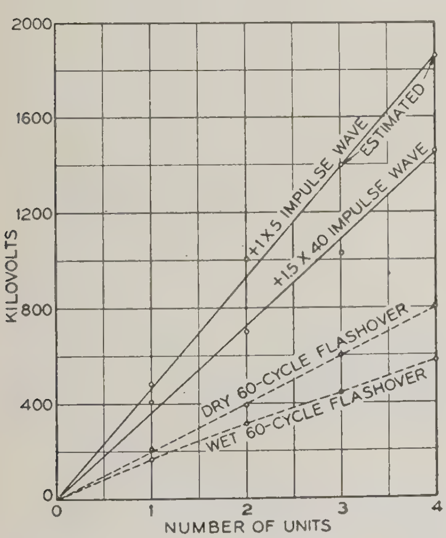


Fig. 5. Flashover voltages of coupling capacitor assemblies

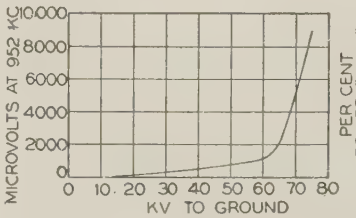
Solid lines—60 cycle flashover values

Dashed lines—impulse flashover values

holding test, and dry 60 cycle flashover. Capacitance measurements are allowed to vary between the limits of 0.0030 and 0.0033 microfarads at room temperature. Power factor measurements average 0.4 per cent. The high potential test is applied at 175,000 volts. The average dry 60-cycle flashover is 210,000 volts, with a permissible tolerance of −5 per cent. In the case of units for the bottom section of the capacitor, an additional test is made on the 15 kv bushing in the base, and the protective gap is adjusted to its prescribed setting (0.26 inches).

Characteristics

Dry and wet 60 cycle flashover voltages, and impulse flashover voltages measured with 1 × 5 and 1.5 × 40 microsecond waves, are shown in figure



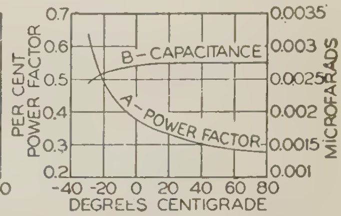


Fig. 6 (left). Radio noise characteristic of coupling capacitor unit at 40 degrees centigrade

Fig. 7 (right). Power factor-temperature and capacitance-temperature characteristics of the coupling capacitor

A—60 cycle power factor versus temperature, at operating voltage

B—Capacitance versus temperature

5 for series combinations of from 1 to 4 units. The comparative 60 cycle and positive characteristics of these coupling capacitors and the corresponding coordination gaps are shown in table I.

Voltage distribution along the stack of a specially constructed unit with taps, which was measured at 120 volts, 60 cycles, and at 110 volts, 150 kilocycles, was found to be practically linear. Measurements of radio frequency voltage at 952 kilocycles were made for assurance that these capacitors would have no undue effect upon radio reception. The data are plotted in figure 6.

Variation of 60 cycle power factor with temperature changes over the operating range was measured,

Table I—Flashover Voltages (Kv) of Capacitors and Gaps

Operating Voltage—Kv	Apparatus	60 Cycle Wet FO	60 Cycle Dry FO	60 Cycle 1 Min.	Positive Impulse Flashover 1.5×40	Positive Impulse Flashover 1×5
69	Capacitor	170	210	175	410	485
	Gap		205		335	420
138	Capacitor	320	390	325	700	1,005
	Gap		410		630	800
230	Capacitor	450	600	530	1,030	1,400
	Gap		680		1,000	1,310
287	Capacitor	585	800	660	1,460	1,860
	Gap		850		1,240	1,630

Note 1. Dry flashover voltages corrected to 25 degrees centigrade, 760 millimeters mercury, and 6.5 grains per cubic foot humidity.
Note 2. Wet flashover voltages corrected to 25 degrees centigrade, 760 millimeters mercury, 12,000 ohms per cubic centimeter water resistivity, and 0.01 inch per minute precipitation at 45 degrees inclination.
Note 3. All flashover voltages are of average values, with a permissible tolerance of −5 per cent.

and is shown in figure 7*A*. It is interesting that this capacitor has a negative temperature coefficient, so that within the operating range the power factor diminishes as the temperature increases.

Table II—Power Factor Tests

Internal Temperature	Per Cent Power Factor	
	50 Kilocycles	150 Kilocycles
50 degrees centigrade	0.85	1.24
80 degrees centigrade	0.47	

Test for power factor values within the carrier-current frequency range are recorded in table II. There is some variation in capacitance with temperature but this is comparatively small throughout the operating range. A curve of capacitance versus temperature is shown in figure 7*B*.

Tests were made to determine the temperature rise at working voltage, 60 cycles, and with carrier current of 50 kilocycles and 150 kilocycles frequency. From these tests the carrier current ratings in table III were derived. All ratings are based upon a maximum of 15 degrees centigrade internal rise over a 40 degree centigrade ambient, which corresponds to about 25 watts loss per unit.

Table III—Carrier Current Ratings

Frequency in Kilocycles per Second	Amperes per Channel		
	1 Channel	2 Channels	3 Channels
50	1.37	0.97	0.79
100	1.57	1.11	0.90
150	1.93	1.36	1.11

Mechanical tests were made to determine the tensile and transverse strength of the units and the factors of safety under suspension mounting and under wind pressure when base mounted. Tension tests were carried to 10,000 pounds without failure. This represents a factor of safety of 8 for suspension mounting of 4 units with potential device attached. Tests on the fiber studs which clamp the capacitor rolls and serve as an emergency tension member in the event of accidental breakage of the porcelain, indicate a satisfactory strength.

Transverse tests, made by applying horizontal force at the top of the unit while the bottom was held rigidly in place, gave results averaging 2,000 pounds to produce failure. With wind pressure of hurricane force, a base mounted stack of 4 units has a safety factor of 4.5.

Trial methods of packing for shipment resulted in the adoption of a special type of packing case with a felt base, and with outriggers and special precautions to insure being maintained in an upright position. Variations of this method, involving 2 or more units in a package, are contemplated for special conditions such as water shipments.

Resonant Lines for Frequency Control

Vacuum tube oscillators for radio frequency signals above 25 megacycles may be controlled with a high degree of precision by resonant lines, and at lower frequencies may be used to obtain a larger power output than is obtainable from crystal oscillators. The general principles of the design of concentric conductor lines and means for compensating temperature changes are discussed in this paper. Line controlled oscillators may be used with frequency multipliers, or to control oscillators at lower frequencies.

By
C. W. HANSELL
ASSOCIATE A.I.E.E.

R. C. A. Communications, Inc., Rocky Point, N. Y.

IN a previous A.I.E.E. paper[1] F. E. Terman indicated that resonant lines may be used to control the frequency of oscillators with a high degree of precision, and mention was made of the use of lines for this purpose in the transmitters employed by the Mutual Telephone Company of Honolulu in the radio telephone system for interconnecting the Hawaiian Islands. The survey transmitters used to demonstrate the possibility of setting up the Hawaiian interisland system, which later formed the basis of design for commercial equipment supplied by the RCA Victor Company, were built by the transmitter research and development laboratory of R.C.A. Communications, Inc., in the summer of 1929.[2] In the intervening 6 years the laboratory has made considerable progess in the design and application of resonant lines to transmitter frequency control. The results have been so satisfactory that it is believed line control will come into very general use in transmitters having outputs above 25 megacycles.

General Principles of Frequency Control

In a vacuum tube oscillator the most common sources of frequency variation are:

1. Variable reaction and loading from the load circuit.

A paper recommended for publication by the A.I.E.E. committee on communication, and scheduled for discussion at the A.I.E.E. Pacific Coast convention, Seattle, Wash., Aug. 27–30, 1935. Manuscript submitted June 3, 1935; released for publication July 1, 1935.

1. For all numbered references see list at end of paper.

2. Fluctuation in tube impedances due to alternating components of power supply.

3. Variations in circuit dimensions due to variation in temperature.

4. Mechanical vibration.

To reduce or overcome the effects of these sources of frequency variation the first requirement is an oscillatory circuit having an extremely high frequency selectivity, or sharpness of tuning, and an ability to store up oscillatory energy which is very great in comparison with the changes in energy caused by the sources of frequency variation. Resonant lines of correct design are capable of meeting these requirements.

Design of Uniform Lines

A satisfactory form of line for frequency control is one made up of concentric tubular conductors of such form that the outer conductor completely encloses the inner conductor. The oscillatory energy is all stored in electromagnetic fields between the 2 conductors and there is no radiation or undesired coupling to external objects and circuits.

If the 2 conductors each have uniform diameters throughout their length the minimum length of inner conductor for resonance is substantially a quarter wave length for radio waves corresponding to the operating frequency. The wave length is the velocity of light, 300,000,000 meters per second, divided by the operating frequency in cycles per second. At 25 megacycles the required length of inner conductor will therefore be about 3 meters or 9.84 feet and at higher frequencies it will be proportionally less.

The ratio of diameters of the conductors in a uniform line, to obtain a minimum power factor and maximum frequency selectivity, should be 3.6.[1,3,4] The power factor will be inversely proportional to the diameters of the conductors, assuming a fixed ratio of diameters, and therefore the frequency selectivity will be directly proportional to the diameters. To obtain a line capable of almost completely

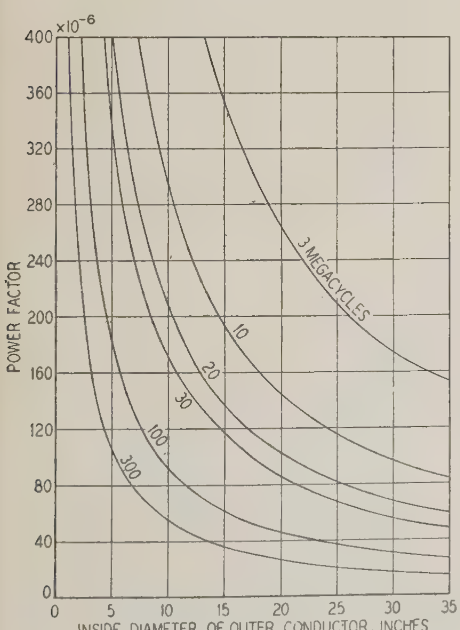


Fig. 1. Power factor curves for concentric conductor lines; ratio of diameters of conducting surfaces 3.6

determining the frequency of an oscillator the diameters should be made as large as possible.

When large diameters are used the length of line need be only a quarter or a half wave to store all the oscillatory energy required without flashing over or rising excessively in temperature due to losses. For most applications one or the other of these lengths

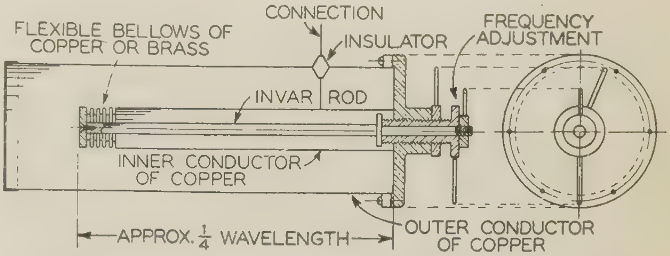


Fig. 2. Arrangement for preventing change of inner conductor length with temperature

will be used. For very high frequencies, above about 100 megacycles (3 meters wave length) the length of a quarter or half wave line may become inconveniently short in relation to the desired diameters. In such cases lines of greater length will sometimes be found desirable.

Copper is the most satisfactory common material to use for constructing the lines. Silver plating the copper conducting surfaces, particularly that of the inner conductor, may be justified in some cases but usually it will be more economical to obtain an equal improvement by increasing the diameters of plain copper conductors.

Aluminum may be used in some instances to save weight but the ultimate gain in using it is small. It has higher resistivity, requiring larger diameters, which in turn requires thicker material for rigidity. Joints, which must be made very carefully to avoid insertion of resistance, are much harder to make with aluminum than with copper. Aluminum also has a higher temperature coefficient of expansion and has lower heat conductivity, tending to permit greater differences in temperature between inner and outer conductors.

The calculated power factors of concentric conductor copper lines having a ratio of diameters for the conducting surfaces of 3.6 are shown in figure 1. The power factors for frequencies other than those shown may be determined readily from the relation that power factor is inversely proportional to the square root of the frequency.

From this figure it will be noted that, at 100 megacycles, for example, using a line 18 inches in diameter, the power factor will be only about 52.5×10^{-6}. For each watt of power input, at the resonant frequency, the line could be made to maintain about 19,000 volt-amperes of oscillatory energy. The length of inner conductor required for quarter wave resonance would be about 29.5 inches and the overall dimensions for the whole line would be about 18 by 18 by 48 inches.

Slow changes in ambient temperature will change all dimensions of the line in proportion to tempera-

ture at a rate corresponding to the linear coefficient of expansion of the material. For copper the coefficient of expansion is about 16.8 parts per million per degree centigrade. Since the ratio of diameters of inner and outer conductors will not change with changes in temperature, the electrical properties per unit of length will not change and the variation in natural frequency of the line will correspond fairly closely to the variation in length only. The frequency-temperature coefficient for a copper line will therefore be about 16.8 parts per million per degree centigrade.

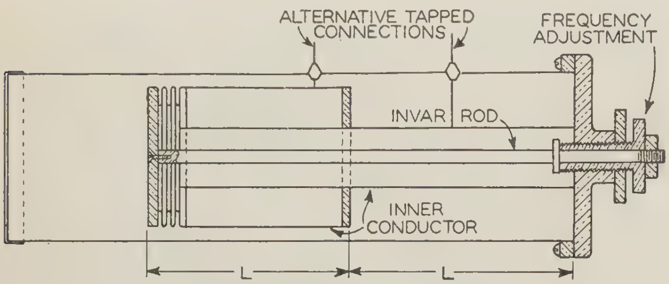


Fig. 3. Resonant line using 2 inner conductors to reduce length

Variations in frequency as the result of variations in ambient temperature may be reduced to any desired degree by temperature control but a simpler and more satisfactory arrangement is to hold the length of inner conductor constant in spite of variations in temperature. This may be done by making a small section of inner conductor out of a flexible metal bellows and then using a rod of invar, or other low temperature coefficient material, to hold the over-all length constant. Figure 2 is a cross-sectional view of such an arrangement. It provides an additional advantage in that the bellows and adjustable length of invar rod permit small variations in length of the inner conductor to adjust the frequency exactly to any desired value.

In addition to ambient temperature variations changing the frequency we must also consider the changes in dimensions from unequal temperatures set up by losses in the line when an oscillator is started. These changes may cause a transient frequency change when a line of the type shown in figure 2 is warming up. Their effect may be made small by using lines of large dimensions and of heavy material which will distribute the heat rapidly. Forced air circulation inside the inner conductor is beneficial but will be required only in special cases. Constructing the whole line of low temperature coefficient material with copper or silver plating on the conducting surfaces would solve the temperature coefficient problem completely and application of this method awaits only commercial production of these materials in the form of large tubes and plates.

Design of Nonuniform Lines

In many instances, particularly at frequencies below 50 megacycles, the length required for a quarter wave line of uniform diameters is objectionable. The length may be reduced without change in resonant frequency and without much change in power factor by using 2 diameters of inner conductor as shown in cross section in figure 3.

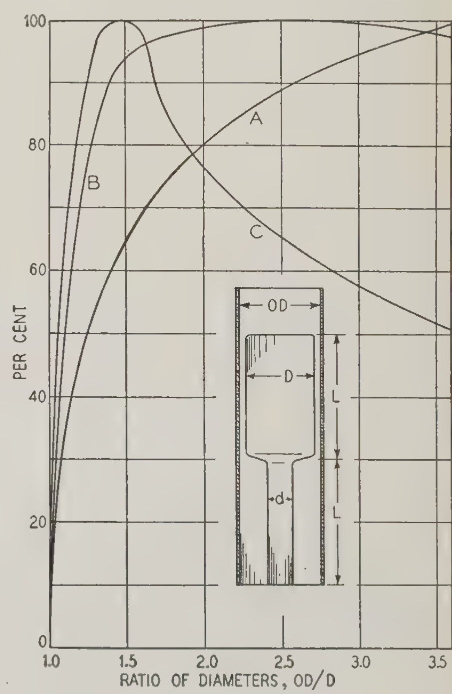
In this arrangement the smaller diameter inner conductor may be considered to be an effective inductance and the larger diameter inner conductor an effective capacitance. The inductance and capacitance each change in value by very nearly the same percentage with change in ambient temperature. If they are made substantially equal in length, and the sum of their lengths is held constant by means of the section of bellows and invar rod, then the frequency will not change appreciably with change in ambient temperature. A rise in temperature will increase the inductance but decrease the capacitance by an equal percentage and so balance out the effect on the frequency.

It would be difficult to lay down definite rules for designing this type of line because of the wide variations possible. In general the clearance between the end of the line and the outer casing must be great enough to withstand the required maximum voltage. This and the diameter of the outer conductor will determine the limit of shortening possible in each case. The power factor will be substantially the same as if a uniform line were used. The ratio of the diameter of outer conductor to that of the smaller of the inner conductors should still be substantially 3.6 for minimum power factor but considerable variation in ratio can be permitted before the power factor begins to increase rapidly. (See figure 4.)

Line Controlled Oscillator Circuits

Resonant lines may be used to control the frequency of oscillators in many circuit combinations. One circuit for use with a single 3-element tube is

Fig. 4. Variation in over-all length of the 2 inner conductors, OD/d = 3.6 (A); variation of permissible voltage at end of line, conductor corners slightly rounded (B); and variation in energy storage rating in volt-amperes (C) for various ratios between inside diameter of outer conductor and outside diameter of the larger of the inner conductors in a nonuniform line



shown in abbreviated schematic form in figure 5. In this arrangement the line is used as a tuned circuit connected between grid and cathode. The anode is provided with a split balanced output circuit. Between the end of this circuit, opposite the anode, and the grid an adjustable capacitor is provided by means of which the regeneration may be controlled. In practice oscillations may be obtained with the capacitor adjusted either above or below a value equal to the anode to grid capacitance of the tube. Usually it is best to adjust the capacitor to a value higher than that of the tube.

If we assume that the output from the oscillator to the next stage is not very great, which is a desirable condition, then the power or resistive component of input to the line causes a phase shift in the radio frequency voltage applied to the grid which is lagging when the capacitor is adjusted for less than the balancing value and leading when the capacitor is adjusted for more than the balancing value. At very high frequencies electron travel time causes a very appreciable phase lag in radio frequency electron currents through the tube in response to grid potential variations. This lag tends to reduce the output and efficiency of the tube. By employing the circuit adjustment which gives the grid excitation an advance in phase we may compen-

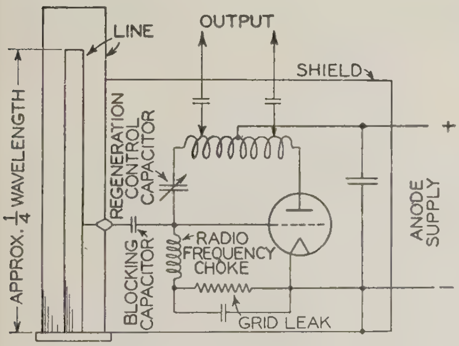


Fig. 5. Single tube oscillator circuit

sate for the electron current phase lag. The difference in performance of the oscillator with one adjustment or the other of the regeneration control capacitor is sometimes very pronounced, particularly when the oscillators are operated near the upper frequency limit of the tubes and when a relatively large proportion of the power is being used in the line.

The circuit of figure 5 is well adapted to supplying

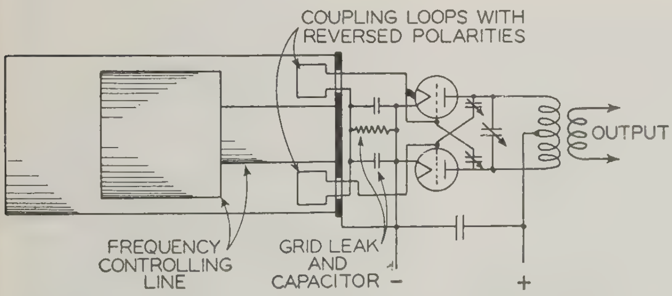


Fig. 6. Circuit of push-pull oscillator using a single nonuniform line

radio frequency excitation to the grids of 2 power amplifier tubes in a balanced or push-pull circuit. Usually the oscillator and amplifier tubes will be of a single type, operated from a common anode supply source. This makes a relatively simple, economical, and reliable system.

In figure 6 is shown a schematic circuit diagram

Fig. 7. Arrangement of apparatus at typical transmitter for 13.42 megacycles, showing U-shaped line for frequency control

of a balanced or push-pull oscillator having its frequency determined by a single nonuniform line. The operation of this circuit is very similar to that shown in figure 5 except that the grid circuits are inductively instead of conductively coupled to the line. This inductive coupling is accomplished by placing 2 single-turn coils radially in the space between the inner and outer cylinders and connecting so as to impress radio frequency voltages of opposite phase on the grids of the tubes.

In the circuits of both figures 5 and 6 negative continuous potential from rectified grid current is applied to the grids of the tubes through a grid leak or grid biasing resistor. The radio frequency bypass capacitor for this resistor should be small enough to prevent appreciable phase lag in grid bias voltage variations as the result of fluctuations in anode voltage or a-c cathode heating currents. The grid leak biasing makes the grids act as a substantially constant radio frequency resistance, in spite of power supply fluctuations, and reduces undesired frequency modulations which might appear if a fixed bias voltage were used.

Application of Line Controlled Oscillators to Transmitters

In applying line controlled oscillators to transmitters where frequency stability is very important it is desirable to protect the oscillator from the effects of antenna circuit variations by interposing one or more amplifier stages between them. When the oscillator is followed by a single stage amplifier, either neutralized or screen grid, the effect of antenna circuit variations upon the frequency is usually reduced to a small percentage of the effect which would be caused by coupling the oscillator directly

to the antenna and at the same time the power output from the amplifier may be much greater.[5,6]

For very high frequency transmitters it is often desirable to operate the oscillator at a half or a third of the final output frequency in order to improve its output and efficiency and to obtain more convenient dimensions of the line and circuits. The oscillator then supplies the input to a vacuum tube frequency multiplier which may, in turn, be followed by a power amplifier. The use of frequency multiplication is an aid to reducing feedback couplings to the oscillator which might tend to introduce frequency variations.[7]

In relatively low frequency transmitters where the lines tend to be excessively large it is sometimes desirable to operate the line controlled oscillator at 2, 3, or more times the final output frequency. The line controlled oscillator then supplies input to a lower frequency oscillator in such a way as to lock or synchronize the frequencies of both at an exact multiple relation. The lower frequency oscillator may then be followed by one or more power amplifiers.

Examples of Experimental and Commercial Applications

Up to the time of writing this paper there have been some 25 or 30 transmitters with resonant line frequency control built by R.C.A. Communications, Inc., and the RCA Manufacturing Company. More are being built. These transmitters range in frequency from 6.725 to 450 megacycles and in power output from about 10 watts to 30 kilowatts. About half of these have been built for commercial service or for use as models for commercial equipment. Some typical examples of these transmitters are shown in figures 7, 8, and 9.

The general arrangement of frequency controlling line, master oscillator, and power amplifier of WHR, operating at 13.42 megacycles with 30 kw, is shown in figure 7. This transmitter is installed at the Rocky Point station and has been in regular commercial service since the latter part of 1933. It has a record of frequency stability exceeding that of most other high frequency transmitters including crystal controlled transmitters. The length of line in this transmitter is a half wave length and, to save space, is bent into the shape of the letter U. The diameter of outer pipe is 20 inches and that of the inner pipe 5.5 inches. Compensation for temperature variation is obtained by means of a variable capacitor operated directly by expansion and contraction of oil in a pipe exposed to the same temperature variations as the line.

Figure 8 is a view of W2XBN, operating at 91.8 megacycles, installed on the top floor of the Continental Bank Building at 30 Broad Street, New York, N. Y. This transmitter was installed for multiplex transmission to New Brunswick, N. J. It provides circuits connecting the central traffic office at 64 Broad Street with the New Brunswick station for controlling transoceanic and transcontinental transmitters located there.

A transmitter located on the roof of the RCA Building, New York, N. Y., for the purpose of making propagation measurements on a range of frequencies above 25 megacycles is shown in figure 9. The pipe shown to the left of the transmitter extends above the roof of the building to support the antenna and carry the transmission line to it.

The advantage of lines as compared with piezoelectric crystals for frequency control for transmitter output frequencies of 6 to 20 megacycles lies principally in the power which may be generated in the oscillator. The output of crystal oscillators is usually less than 1 watt and seldom exceeds 5 watts while it is practical to build line controlled oscillators with outputs of 1 kw or more. This materially re-

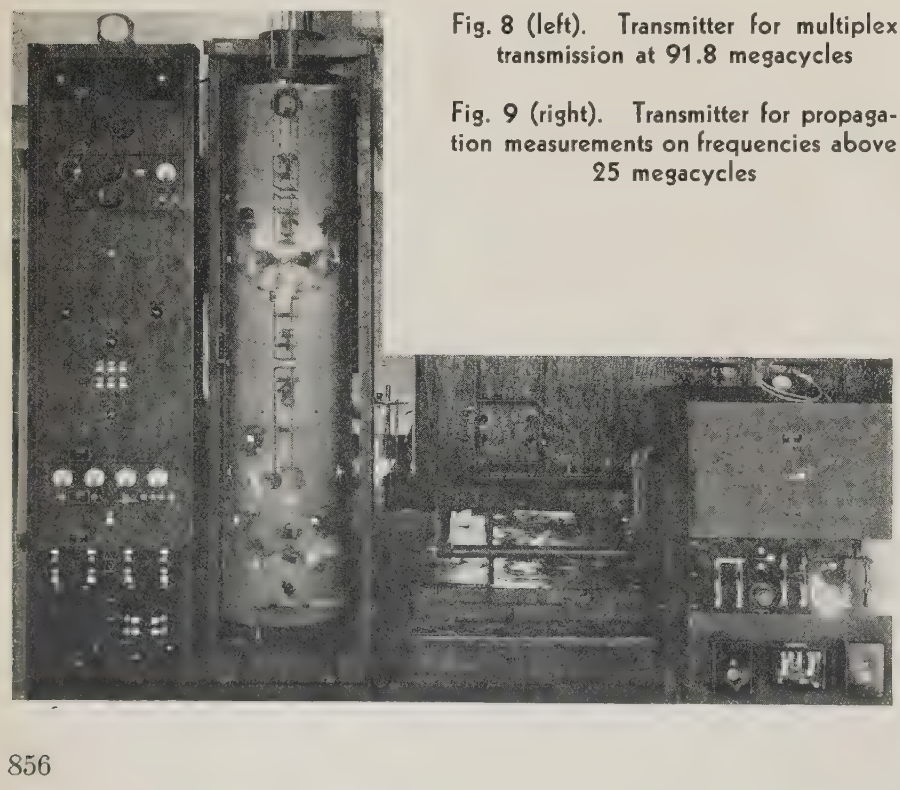
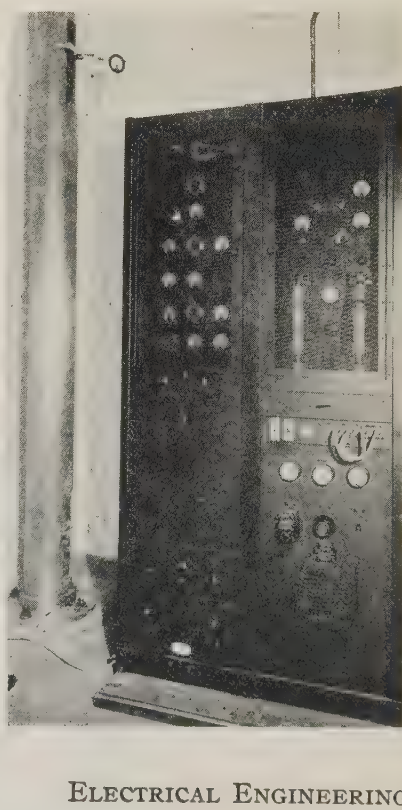


Fig. 8 (left). Transmitter for multiplex transmission at 91.8 megacycles

Fig. 9 (right). Transmitter for propagation measurements on frequencies above 25 megacycles



duces the number of stages required in a high powered transmitter and thus increases its reliability and often reduces its cost.

The selectivity of the crystals normally used in these transmitters may be judged by their power factor, which is of the order of 40×10^{-6}. The selectivity of the line used in the transmitter shown in figure 7 which operates at a comparable output frequency is less than the crystal, since its power factor is of the order of 125×10^{-6}. This indicates that the crystal is capable of a greater accuracy of control but in practice it has been found difficult to realize this advantage.

At output frequencies above 20 megacycles the line type of frequency control has marked advantages over a crystal since the line can be built to resonate at the desired output frequency, while with crystal control the number of frequency multiplier stages required would become excessive. Also, as shown in figure 1, the frequency selectivity of the line improves with frequency and can be made to exceed that of the crystal.

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A Radio Interference Measuring Instrument

Consideration of the factors involved in radio interference field strength measurements indicates that the effective values measured by conventional methods are inadequate for describing the interfering effect of the disturbing radiation. The instrument described in this paper provides a means for measuring with acceptable accuracy both crest and effective values of interference field strength, the ratio of which agrees with observed discrepancies between effective and apparent values.

By

F. O. McMILLAN
FELLOW A.I.E.E.
Oregon State College, Corvallis, Ore.

H. G. BARNETT
ASSOCIATE A.I.E.E.
U. S. Bureau of Fisheries, Portland, Ore.

THE elimination and mitigation of radio interference is a problem of great importance because of the almost universal use of radio receivers. Radio reception with modern receivers is interfered with by many different kinds of phenomena that originate in nature and from man-made apparatus. The most insignificant electromagnetic radiation may cause serious disturbances if it occurs in the band of frequencies used for radio communication. Therefore, the measurement and evaluation of the interference characteristics of interfering radiations is important.

Measurements of radio interference taken at various times, with different instruments, by different individuals, and in widely separated geographical locations, show that the effective or root mean square field strength of radio interference from transmission lines and other similar sources gives values that are extremely low in comparison with the modulated continuous wave field strength required to produce the same apparent volume of sound from a radio receiving set.[1,2] These field strengths were measured with instruments designed to measure the effective value of the radiation from radio broadcast transmitters, and the measurements were made with an accuracy that was within 10 per cent of the absolute root mean square value or better. Notwithstanding this order of accuracy, which is considered satisfactory for such measurements, the apparent strength of the received interference signal was observed to be from 3 to 10 times that of a continuous wave signal having the same measured root mean square value. It is therefore apparent that in the control of radio interference it is not practical to establish maximum permissible interference field strength levels on the basis that the effective value of the field strength of a continuous wave radio signal and the effective value of the field strength of radio interference are comparable in the effect they produce in a radio receiver.

The lack of correlation between effective value measurements of discontinuous and continuous field

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1. For all numbered references see list at end of paper.

strengths was repeatedly confirmed during the early stages of an investigation of the radio interference originating from high voltage transmission lines at Oregon State College. These experimental results show conclusively that it is necessary to know more about an interferering radiation than the effective

Fig. 1. Crest indicating instrument used with field strength set for measuring crest field strength

value of the field strength before it is possible to predict the amount of radio interference it will produce.

The measurement of both the effective and the crest field strength makes it possible to determine the ratio of the crest to the effective value, or the crest factor, which defines the nature of the measured radio interference. When the interfering radiation is discontinuous, with recurring intervals of very low or no field strength at all interposed between relatively short periods of high field strength, a high crest factor will be obtained. When the radiation approaches a continuous series of waves, the crest factor will decrease in value.

This paper describes an instrument that may be used in conjunction with a conventional field strength measuring set for measuring crest field strengths of either sine wave radiation or discontinuous radio interference. Effective and crest field strengths for some typical interfering radiations are reported to show the results obtained with the device and to emphasize the importance and value of such measurements. The instrument is still in the developmental stage, and further experience with it will no doubt suggest desirable improvements and refinements.

Measurement of Effective and Crest Field Strengths

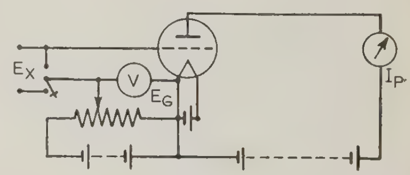
The field strength measuring set used was a portable instrument that has been described in a paper by Axel G. Jensen.[3] Briefly, this set was a superheterodyne receiver having an indicating instrument in the second detector tube plate circuit for indicating the output. The amplification was ajustable over a wide range by a variable gain control and by selecting any part of 3 stages of intermediate frequency amplification. The antenna was of the loop type, and provision was made for introducing a known radio frequency voltage into the loop circuit from a local oscillator so that the absolute value of the field strength could be determined.

Measurements are made by tuning the set and adjusting the amplification so that a reasonable reading is obtained on the output indicating instrument. Then the local signal oscillator frequency is adjusted until it is equal to that of the unknown signal. With the loop turned so that the unknown signal gives a minimum output from the set, the local signal is introduced into the loop circuit and adjusted to give the same reading on the output instrument as was obtained with the unknown signal. From the value of the local signal output required to match the unknown signal and the effective height of the loop, the field strength for the unknown signal can be computed. This method measures the effective value of the local signal, because the output instrument will give the same indication in 2 instances only when the effective voltages impressed on the grid of the detector tube are the same, since this instrument is a permanent magnet type and averages the detector tube plate current which in turn is a square law function of the voltage applied to the grid of the tube.

If a device could be introduced in series with the output instrument which would indicate crest values instead of average values, the locally produced known signal could be adjusted so that its crest value would give the same indication as the unknown signal. Then if the crest factor or crest value of the local signal were known, the crest value of the unknown signal could be calculated. By introducing a resistance of the order of 10,000 ohms into the second detector tube plate circuit, a voltage of several volts can be made available for the operation of a crest indicating device. It was experimentally determined that there was no perceptible distortion of speech or music on a broadcast program by the addition of 0 to 25,000 ohms resistance in the second detector plate circuit. Therefore, the addition of 10,000 ohms resistance in series with the detector tube and the primary of the audio frequency transformer, for the purpose of operating a crest indicating device, was feasible.

The complete instrument for indicating crest field strengths is shown in figure 1. This crest indicating

Fig. 2. Fundamental circuit for vacuum tube crest voltmeter



device is introduced into the field strength measuring set in series with the output microammeter by means of a plug cord, the end of which is shown in the figure at the extreme left end of the instrument. The instrument is essentially a vacuum tube crest voltmeter and may be described by explaining some of its fundamental characteristics.

The general plate rectification method of measuring crest voltages taking advantage of the grid voltage-plate current characteristic is frequently called the null method or slide back method.[4] The operation of this circuit depends on adjusting the grid bias until the plate current is just zero. Figure 2

illustrates how the unknown voltage E_X is applied to the grid in addition to the d-c grid bias voltage E_G. The operation of this crest voltmeter circuit is illustrated graphically in figure 3 for the condition when the grid bias voltage E_G is adjusted so that a small plate current I_P flows at the crest of each positive half cycle of the unknown voltage E_X. When this small pulse of plate current for each cycle just comes to zero, it is evident that the crest value of E_X is equal to $E_G - E_0$. The voltage E_0 is determined with E_X equal to zero, or by operating the switch shown in figure 2 to eliminate E_X.

If a good method of indicating the critical crest point with a well evacuated vacuum tube having a sharp plate current cutoff characteristic is used, the reliability of the results of crest measurements with the null vacuum tube voltmeter circuit is very good. Using a 60-cycle variable voltage, tests with this type of circuit and with either headphones or a microammeter as an indicator gave results that checked the actual crest values very well.

The complete circuit for the crest voltmeter, as developed, is shown in figure 4. The instrument consists of the null vacuum tube crest voltmeter and a 3-electrode gas filled tube indicator circuit. The principle of operation of the indicator is apparent from this diagram. The voltage drop across a resistor in the plate circuit of the null vacuum tube voltmeter stage is impressed on the grid of the grid controlled tube in such a manner that if the grid bias is adjusted very near to the critical ionization potential, the tube will start conducting when a small pulse of current flows through the vacuum tube at the crest of an a-c wave impressed upon the grid of the vacuum tube. After ionization is initiated in the controlled tube, the plate current is independent of the grid voltage. Therefore, the plate circuit constants can be adjusted to permit a large current flow for operating a suitable device to indicate the crest adjustment.

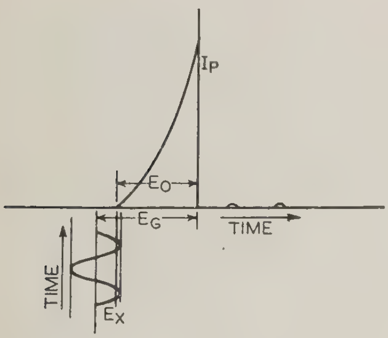


Fig. 3. General grid voltage-plate current characteristic for a vacuum tube

Operation of Instrument

The functioning of the complete instrument may be explained by following through one complete operation with the aid of figure 4. When a current flows through R_1 a voltage drop E_X is superimposed on E_G, the grid bias of the crest voltmeter tube. Now assume that E_G is adjusted so that at the crest of each positive half cycle of the alternating voltage E_X a small amount of current flows in the plate circuit of the crest voltmeter tube. Also consider that E_2 is adjusted so that if a small positive voltage is added to it the grid control led tube will ionize and begin to conduct. Then when the first positive half cycle of alternating voltage is impressed on the input to the crest voltmeter a small

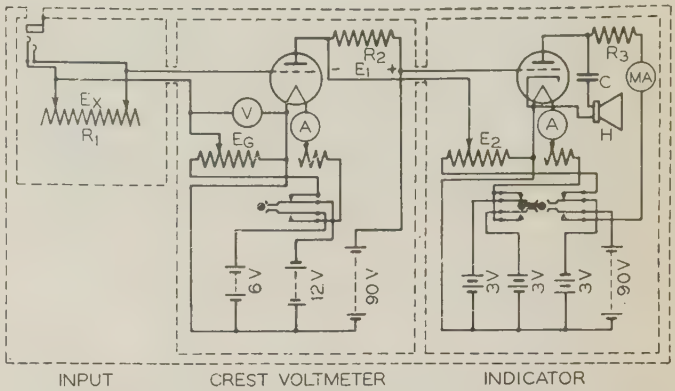


Fig. 4. Circuit of crest indicating instrument

current will flow through R_2 at the crest of E_X. The voltage drop across R_2 will have the polarity indicated in the diagram. This voltage E_1 is added to E_2 in such a manner that the potential of the grid of the indicator tube is decreased, permitting the gas in this tube to ionize and conduct. If the tube were not paralleled by the circuit H-C, the current through it would be limited by the resistance R_3 and the small voltage drop in the tube. This would permit a relatively large current to flow and would cause a conspicuous deflection on the milliammeter in series with R_3. The resistance R_2 is 250,000 ohms so that a voltmeter tube plate current of 1.0 microampere would give E_1 a value of 0.25 volt. This voltage is greater than the range of variations in the critical grid control potential for the indicator tube under a wide variety of conditions, and therefore insures reliable operation at all times.

The use of a grid controlled tube as the indicator for the vacuum tube crest voltmeter adds considerable flexibility to the instrument. By using the first stage of this arrangement essentially as an amplifier any part of the grid potential-plate current characteristic curve can be utilized for operation. By adjusting the grid bias on the grid controlled tube, the indicator can be set to operate at any desired value of current in the plate circuit of the vacuum tube.

The circuit H-C in parallel with the indicator tube is fundamentally an inverter circuit, in which H is a relatively low resistance headphone and C a condenser of 0.06 microfarad capacitance. As long as the tube is in a nonconducting state, the voltage across the condenser is equal to the battery voltage, but as soon as the tube begins conducting, the condenser is discharged rapidly through the tube. The rate of this discharge is limited only by the impedance of the headphones and the low voltage drop in the tube. Hence, the condenser continues to discharge until the voltage across the condenser and tube is too

Fig. 5. Crest indicating instrument showing arrangement of apparatus and shielding compartments

low to support ionization of the gas in the tube. Then conduction through the tube ceases, and the condenser is once again charged up to either the battery voltage or the critical static ionization potential of the tube, whichever is lower.

This inverter circuit provides automatic resetting of the indicator each time the tube is tripped by a voltage impulse from the crest voltmeter tube. If it were not for this arrangement, it would be necessary to take the voltage off manually each time the indicator tube became ionized, because the grid loses all control of conduction in the tube as soon as ionization occurs. The convenience of this circuit arrangement is at once obvious and crest voltage measurements are greatly facilitated by this refinement. The headphone H in series with C makes audible the operation of the indicator tube, in addition to the visible deflection of the milliammeter in the plate circuit.

Using a 3 element electron tube with unusually high vacuum to reduce the tube noise in the voltmeter stage, measurements were made of both 60 cycle and damped oscillation voltages. The crest values measured were compared with the crest values determined directly by the cathode ray oscillograph and were found to have a maximum error of less than 3 per cent of the maximum indication. This accuracy was well within the accuracy of the oscillograph indications and was considered to be quite satisfactory for such measurements.

The shielding plan for the circuit is shown by the broken lines in figure 4. This shielding is connected to the shielding of the field strength set through a copper braid on the interconnecting cord. The crest indicator instrument circuit is, therefore, connected to the shielding through the field strength measuring set circuit. The crest indicator circuit is arranged in stages, each stage occupying a separate compartment, as shown by figure 5. These compartments are copper boxes which serve as shielding. A large copper box encases all of the compartments and serves as an additional shield. As shown in the circuit diagram, the shielding compartments are connected together at only one point. These are in turn connected to the outer shielding case at only one point. Connection is made between this point and the field strength measuring set shielding.

The input resistor R_1 is a specially constructed decade unit, variable in steps of 1,000 ohms from 0 to 20,000 ohms, the elements of which comprise a woven fabric in which the conductor constitutes the woof and the insulation material the warp. This gives very low distributed capacitance and practically no inductance. The time constant for the

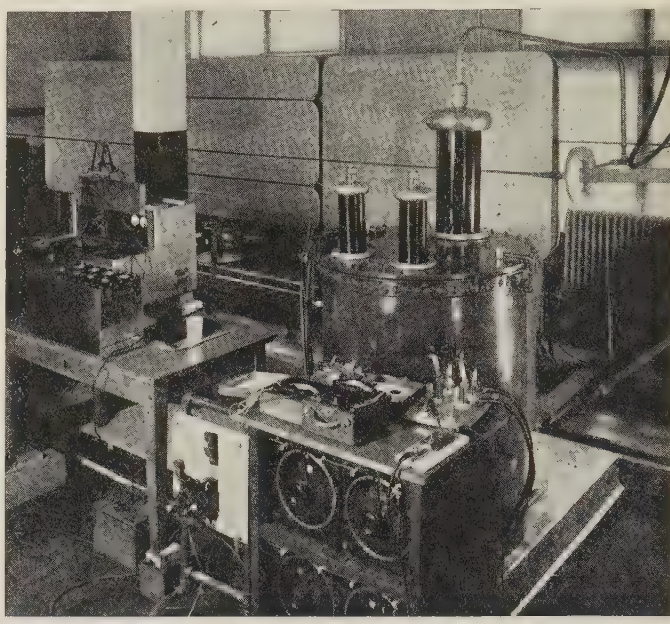


Fig. 6. Laboratory arrangement for making measurements of radio interference from conductor corona

resistor varies between 1×10^{-8} seconds for 1,000 ohms and 7×10^{-8} seconds for 20,000 ohms at 50,000 cycles per second. Studies with the cathode ray oscillograph confirmed the fact that the input resistor has essentially the characteristics of a pure resistance up to 50,000 cycles per second.

In the assembled instrument (figure 1) the input is at the left, the large knobs providing adjustment of input resistance. Next is the voltmeter stage. The instrument at the left indicates the filament current which is adjusted by means of the knob immediately in front of that instrument. The second instrument from the left indicates the value of the grid bias voltage E_G which can be adjusted by the corresponding knob. The indicator stage is at the right end of the instrument, with the indicating milliammeter at the extreme right. The perforations in the middle of the panel in this stage are above the headphone for giving an audible signal of the functioning of the indicator tube. The battery switches are at the extreme front edge of the panel.

A front view of the instrument with panel raised is shown in figure 5. The construction and arrangement of the 3 stages and various parts may be seen. The input resistance is at the left with the voltmeter stage next and the indicator on the right. The arrangement of the shielding boxes may

also be seen; these compartments are mounted and insulated from each other and from the exterior shield by bakelite strips. The compartments are connected together by short pieces of copper tubing through which connections are made from one stage to the next. These conduits fit in the notches shown near the front of the boxes.

In operation the local signal generator of the field strength set, in conjunction with which the crest indicating device is used, is adjusted twice. One adjustment is made to match the reading of the output microammeter on the receiver with the reading for the unknown signal. The other adjustment matches the indication of the crest indicating instrument to the indication for the unknown signal. From the first local signal value, the effective interference field strength may be determined, and from the second the crest value may be computed.

When making observations of interference of the type caused by corona, it is necessary to discriminate somewhat in choosing the crests for the crest measurements. Generally, 2 definite levels of the crest value of interference may be measured. The higher level appears to result from frequent abnormally high crest values of the interference caused by the corona. These intermittent crests occur rather irregularly and seem to have an average frequency of about 5 to 10 per second. These intermittent crest values of field strength are somewhat erratic and unreliable. The lower level of crest values is quite regular and distinct. At this level the audible tone from the crest indicator shows that these regular crest values occur on practically every cycle of the voltage producing the corona. The regular crest value of interference has been used for correlation with the effective value measurements and interference effects in radio receivers.

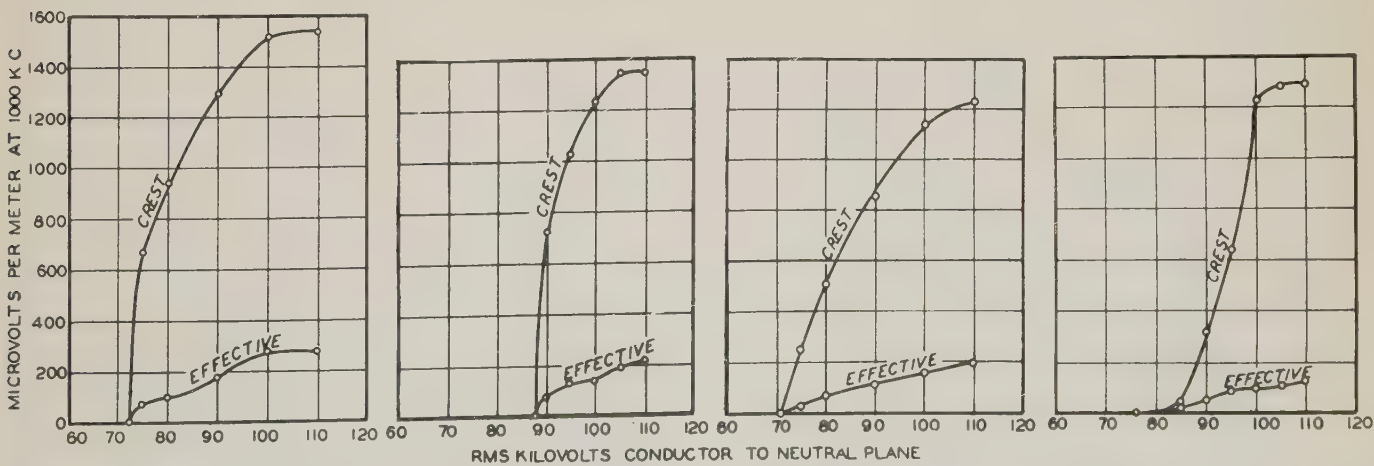
Typical Crest and Effective Field Strength Measurements

The arrangement of apparatus for making measurements of the crest and effective field strengths of interference caused by conductor corona is shown in figure 6.[5] The conductor under observation is suspended between treated maple insulators in front of the sheet iron plates which simulate the neutral plane. The ends of the conductor and insulators are shielded with large metal tori to prevent corona formation at the points of support. The test conductor is spaced 36 inches from the neutral plane, corresponding to a line to line spacing of 6 feet in a conventional transmission circuit. A voltage is applied between the conductor and plates by the testing transformer shown, voltage control being provided by the alternator field rheostats shown in the central foreground.

The arrangement of the measuring instruments is shown in the left foreground of the figure. The conventional effective field strength measuring set is shown on the back of the table, and the crest indicating instrument is immediately in front of the field strength set. The loop antenna is supported on the back of the table in order to obtain adequate coupling with the interfering circuit. The field strength measuring equipment is placed near the test conductor in order to detect the interference caused at the first occurrence of corona. All of the measurements of the interference field strength reported in this paper were made with the field strength set tuned to 1,000 kilocycles.

The effective and crest field strengths, of the radio interference from corona at various voltages on a 2/0 polished copper cable are shown in figure 7. Polished conductors were used for some measurements of conductor corona interference in order to obtain consistent and reproducible results. For such a conductor the crest field strength rises very abruptly as the voltage is increased beyond the critical corona voltage for the conductor. This characteristic corresponds closely with the noise caused in a radio receiver. The crest value of interference is from 5 to 10 times the effective value. In figure 8 are shown the effective and crest field strengths of the radio frequency radiation from corona on a polished 4/0 aluminum cable steel reinforced. The corona interference characteristics for this conductor are essentially the same as those for the copper cable.

Characteristic curves for weathered copper and



Figs. 7–10. Effective and crest field strengths of radio frequency radiation from conductor corona
Cables 36 inches from neutral plane

aluminum cables are shown in figures 9 and 10. The increase of crest field strength immediately above the critical corona voltage is much less abrupt for the weathered conductors than for the polished cables and is less abrupt for the weathered aluminum cable than for the weathered copper cable. These characteristics agree with the audible nature of the disturbance in a radio receiver. The curves are typical of the characteristics obtained for several conductor sizes and spacings by measuring the crest and effective field strengths of the radio frequency radiations resulting from conductor corona.

The field strengths of interference from insulator corona[6,7,8,9] were measured by an arrangement similar to that shown in figure 6 except that a single conductor was suspended in the space occupied by the neutral plates. This conductor was free from corona over the range of the voltages used in the measurements. The insulator under observation was supported on a wooden arm and tied to the conductor with a number 6 tie wire. The insulator pin was connected to ground.

The solid curves in figure 11 show the effective and crest field strengths of interference from corona on a conventional 66 kv porcelain insulator. The interference from this insulator is contrasted with that from conductors by the gradual initial increase in field strength. This again agrees with the audible disturbance caused in a receiver. The interference field strengths for a 66 kv insulator designed to eliminate radio interference are shown by the dashed curves in figure 11. The interference starts at a much higher voltage than it does with the conventional type. Since the curves of radio interference are based on conductor to pin voltage, it should be pointed out that the operating voltage for these insulators is 38.1 kv conductor to pin. As in the case of the conductors, the crest field strengths measured for insulator corona interferences are several times as great as the effective values.

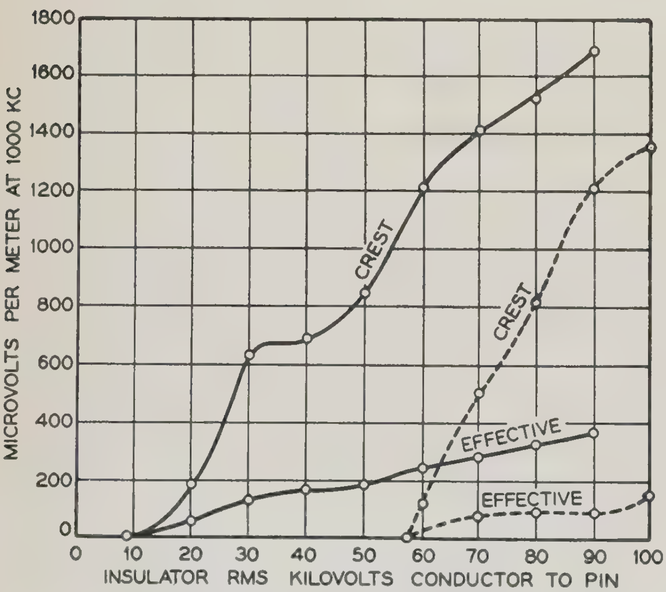


Fig. 11. Effective and crest field strength of radio frequency radiation from insulator corona

Solid curves—conventional 66 kv porcelain insulator
Dashed curves—66 kv porcelain insulator specially designed to eliminate radio interference

The high ratio of the crest value to the effective value found for the interference from both conductors and insulators is characteristic of many types of interfering radiation. These high ratios or crest factors are caused by the discontinuous bursts of electromagnetic radiation produced by the corona discharges. The general characteristic of the interference caused by a conductor in corona is shown in figure 12. This oscillogram shows the conductor to plate voltage and the audio frequency interference output of a radio receiver caused by the conductor corona. From the figure it may be observed that the interference is very high for a short time interval during the negative half cycle and does not recur until the next negative half cycle. As the number of electrodes of opposite polarity and the number of phases with electrodes of one or both polarities are increased, the time interval between successive interfering radiations is reduced and the continuity of the interference is increased. It is, therefore, very important to measure both the effective and crest values of interfering radiations in order to be able to describe adequately their characteristics.

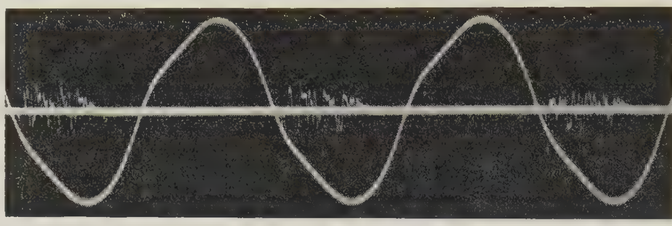


Fig. 12. Oscillogram of conductor to plane voltage and radio interference from conductor corona

The ratios of crest and effective field strengths obtained agree with discrepancies observed between effective field strength measurements and apparent values. This fact indicates that the method of measuring interference described offers a better means of correlating interference measurements with interference effects.

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Diesel Electric Motive Power for Railroads

Recent developments in internal combustion engines have provided a source of mobile motive power for railroads which has shown economies over steam operation in some classes of service. The continuing development of Diesel engines gives promise of their further substitution for steam power, but in the application of this unit, performance characteristics must be considered carefully. The recently developed "streamlined" Diesel electric trains are rather limited in application, but the Diesel engine has an immediate field of application in switching and transfer locomotives. Electrical transmission of power from the Diesel engine to the driving wheels of a train has advantages which make it preferable to any other type of transmission as yet developed.

By
A. H. CANDEE
ASSOCIATE A.I.E.E.

Westinghouse Elec. and Mfg. Co.,
S. Philadelphia Works, Lester, Pa.

THE initial development of internal combustion engines for railroad motive power, which took place during the first quarter of the present century, was based upon the use of gasoline or gasoline substitutes because no Diesel engines had been built which were suitable for the purpose. In 1925, however, the Diesel engine, which already had been successfully used for other applications, was developed to the stage where it could be applied for railroad transportation. In that year, Diesel engines of 200 and 400 horsepower capacities were applied to rail cars of the Canadian National Railways, and a few Diesel locomotives were constructed with 300 horsepower installed engine capacity. There are now nearly 200 Diesel locomotives and more than 50 Diesel rail cars in service or on order, and the application of such units has only begun. When it is considered that the steam locomotive has had over 100 years of intensive development and that the Diesel engine as applied to rail motive power, has had scarcely 10 years of life in the face of serious obstacles, an optimistic view of the field for the Diesel engine in the years to come may be justified.

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THE DIESEL ENGINE

Undoubtedly, most engineers are familiar with the Diesel engine, but for the benefit of those who are not, a brief description may be in order. In general construction the gasoline and the Diesel engines are nearly identical. The former, however, draws in its fuel in the form of a gas, the gasoline being vaporized and mixed with the proper quantity of air. This fuel mixture is then compressed and fired by an electric spark. The Diesel engine draws in nothing but pure air and, after this pure air is compressed, the fuel is sprayed into the cylinders in a very fine vapor and fired by the heat generated by compressing the air. This method of introducing the fuel is the fundamental difference between these engines, and is responsible for the much higher thermal efficiency of the Diesel engine. In the gasoline engine, the maximum compression of the gas fuel mixture must be low enough to guard against preignition of the charge due to heat of compression. In the Diesel engine, the compression pressures may be much higher because only air is involved. The higher temperatures and pressures in the latter case result in greater efficiencies. This also means that the engine parts must be slightly heavier to withstand the higher pressures.

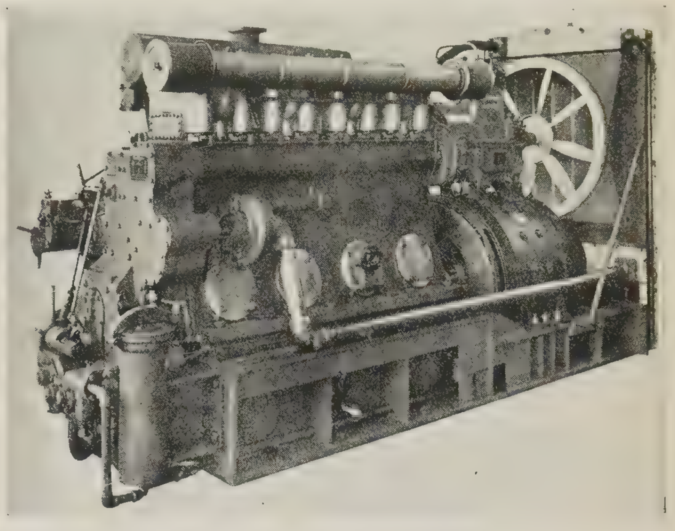

Fig. 1. A Diesel engine rated 265 horsepower, 900 rpm, 4 cycles, and having 4 9 by 12 inch cylinders

The Diesel engine "grew up" as a marine engine; it was of slow speed for direct connection to propellers, and weight was of minor importance. Few Diesel engine manufacturers could foresee sufficient field for the high speed light weight Diesel engine to warrant the high expense of development. The application of such engines to rail propulsion, however, necessitated small dimensions and light weight; with the growing demand, such engines have been

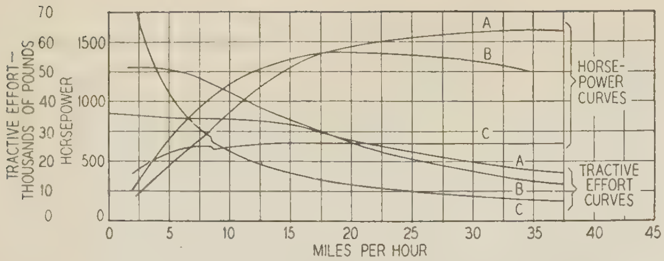

Fig. 2. Curves of horsepower and tractive effort versus speed for steam and Diesel electric locomotives

A—6 wheel steam switching locomotive
B—Consolidation steam locomotive
C—800 horsepower Diesel switching locomotive

developed. The first commercial rail car engine weighed around 30 pounds per horsepower, which compared very favorably with similar sized contemporary gasoline engines, and was a long step forward. This development has been a contributing factor toward the adoption of Diesel engines for rail propulsion purposes.

Reduction in Operating Costs With Diesel Operation

The real basis for the use of the internal combustion engine by the railroads has been and will continue to be reductions in operating costs. Gasoline cars were built and used in quantities because they could be operated by reduced crews, because maintenance expense was lower, and because attendant facilities necessary for steam operation could be eliminated. In rail car work, the Diesel engine has the further advantage of reduced fuel expense. A typical cost comparison of a steam locomotive and train as against a Diesel motor car with a trailer to handle the same service, is shown in table I.

This does not take into account any reduction in attendant facilities, as, in this particular instance, the freight service was still operated by steam, and the coal chutes, water towers, and ash handling equipment were retained.

If this service were handled by a gasoline-engined rail car, the engine maintenance would be slightly higher than the figure for the Diesel engine, and the fuel cost would be approximately the same as coal cost for steam, so that the net saving per year would be reduced from $20,650 per year to approximately $17,000.

The Diesel-engined locomotive had had its christening in switching service. In this class of work, the operating savings, as compared to steam operation, are very pronounced. A typical operating cost comparison is shown in table II. This comparison is of a steam locomotive having a maximum rating of 900 horsepower at the rims of the drivers replaced by a Diesel locomotive developing 425 horsepower at the rail, either locomotive performing the switching work effectively.

Performance, Relative to Steam

In applying Diesel locomotives, it must be recognized that there is a marked difference in the per-

Table I—A Typical Comparison for Passenger Service

Steam Train Investment	$42,707	
Diesel Train Investment		$81,646
	Dollars per Train Mile	
	Steam	Diesel
Crew wages	$0.2841	$0.2215
Motive power repairs	0.2791	0.0440
Car repairs	0.0376	0.0376
Fuel	0.1036	0.0310
Lubrication	0.0067	0.0100
Water	0.0253	0.0000
Enginehouse expense	0.1012	0.0120
Supplies	0.0079	0.0079
Total operating cost	$0.8455	$0.3640
Interest on investment	$0.0528	$0.0982
Motive power depreciation	0.0066	0.0380
Trailer depreciation	0.0154	0.0092
Fixed charges	$0.0748	$0.1454
Grand total	$0.9203	$0.5094
Savings per year (50,250 miles per year)	$20,650	

formance curves of steam and Diesel locomotives. This is best illustrated by figure 2, which shows the performance of an 800 horsepower (engine rating) Diesel switcher, a 6 wheel steam switcher, and a consolidation steam locomotive. The horsepower curves shown represent the power developed at the rail. It may be seen that the Diesel unit is of relatively constant horsepower, while the steam units are of variable power developing their maximum power at 20 miles per hour or above.

It has been shown repeatedly that Diesel locomotives of limited installed engine power can compete successfully in switching service with steam motive power of much higher potential horsepower capacity. The Diesel superiority lies in the high starting tractive force obtainable. Electric drive of the axles provides smooth and continuous application of torque, and reduces the tendency of wheels to slip, whereas the steam locomotive drive produces 4 distinct impulses at the wheels in each revolution. The minimum torque in a 90 degree rotation of the wheels is 29 per cent less than the maximum during this same period. Therefore, there is a pulsating torque varying from 71 per cent to 100 per cent (with an average of 89 per cent) of the maximum

Fig. 3. Switching comparison of 0–6–0 steam locomotive and 530 horsepower Diesel locomotive, with 1,500 tons trailing load, on level track

The Diesel locomotive is the faster on runs less than 1,740 feet

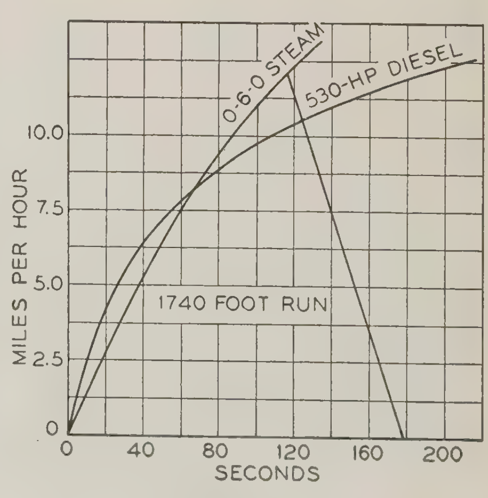

Table II—A Typical Cost Comparison for Switching Service

	Dollars per Day	
	Steam	Diesel
Wages—engineer	$ 22.20	$22.20
Wages—fireman	17.43	0.00
Fuel	15.00	3.60
Lubricants	0.36	1.61
Water	1.15	0.00
Repairs	54.48	14.30
Enginehouse expense	7.00	2.00
Supplies	1.00	1.00
Total operating cost	$118.62	$44.71
Depreciation	$ 1.20	$ 7.20
Total expense	$119.82	$51.91
Savings by Diesels per day		$67.91
Savings by Diesels per year		$24,800.00
Return on investment	Approx. 40%	

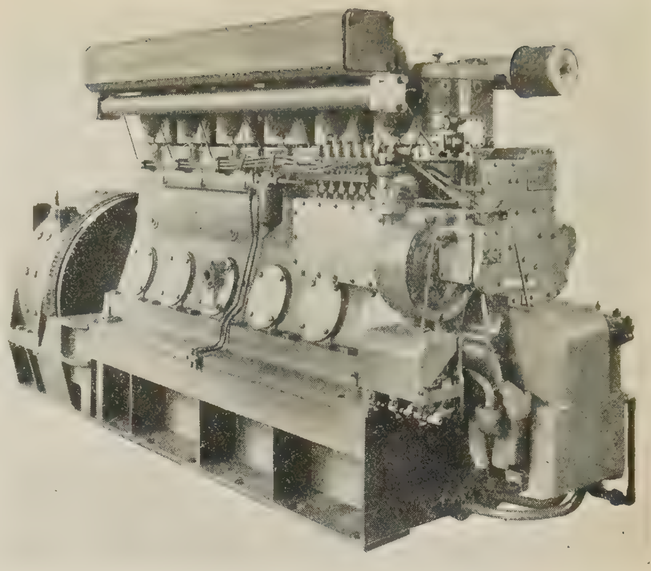

Fig. 5. A Diesel engine rated 400 horsepower, 900 rpm, 4 cycles, and having 6 9 by 12 inch cylinders

available. Obviously, the useful tractive force of the electrically driven wheels may be considerably higher (without exceeding the adhesive limit) than that of wheels driven by reciprocating engines through side rods. It has been demonstrated in service that this may be 20 to 30 per cent greater than the useful steam tractive force for equivalent weight on drivers.

The effect of high starting tractive force in the acceleration of a train is shown by figure 3. It may be noted that the area under the curve represents distance (speed × time) and that the Diesel locomotive gains considerable distance over the steam locomotive during the first 67 seconds, and, in order to regain this distance, the steam locomotive must accelerate to a higher speed than the Diesel. If both locomotives then brake to a stop at the end of 178 seconds, they will have each covered exactly the same distance (1740 feet) and for any shorter distance, the Diesel will have consumed less time.

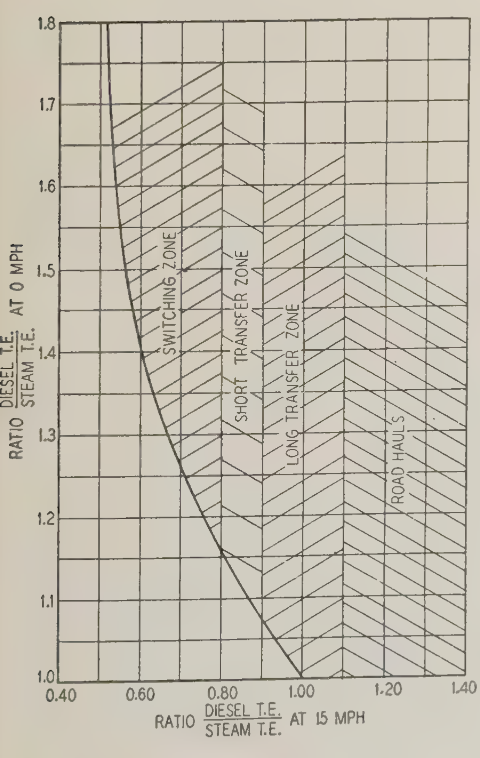

Fig. 4. Application guide for Diesel electric locomotives relative to a steam locomotive (approximate)

The effect of high starting tractive effort, as compared to that of the steam locomotive, may best be illustrated by figure 4, which is the result of a great many comparisons such as that shown in figure 3. For switching work, a Diesel locomotive with a relatively high starting tractive effort, as compared to steam, will compare favorably even when the horsepower is low, whereas when the initial tractive effort approaches more nearly that of the steam unit, more Diesel engine horsepower is necessary to perform the same work, horsepower being represented on the curve in proportion to tractive effort at 15 miles per hour. Thus, if the initial starting tractive effort of the Diesel locomotive (usually figured at 30 per cent of the weight on drivers, which value is permissible due to the uniform torque of electric motor drive) is 50 per cent higher than that of the steam locomotive, the tractive effort at 15 miles per hour need be but 60 per cent of that of the steam unit, to fall within the switching zone. This means that the horsepower developed at the driving wheels need be but 60 per cent of that of the steam locomotive at that speed in order for the 2 units to be comparable in switching work. If the service includes frequent short transfer hauls the Diesel horsepower should be 80 per cent to 85 per cent of the steam horsepower at the wheels. However, when these switchers are used in transfer or road service, the limited horsepower seriously affects the train performance, and the effect of rapid acceleration becomes of less importance. This means that progressively more Diesel power is required for short transfer work, long transfer work, and road hauls. This is also shown by figure 4. In calculating the steam locomotive performance curve any standard method may be used, but since it has been found that actual road performance is usually very considerably less than the calculated curve, the tractive effort

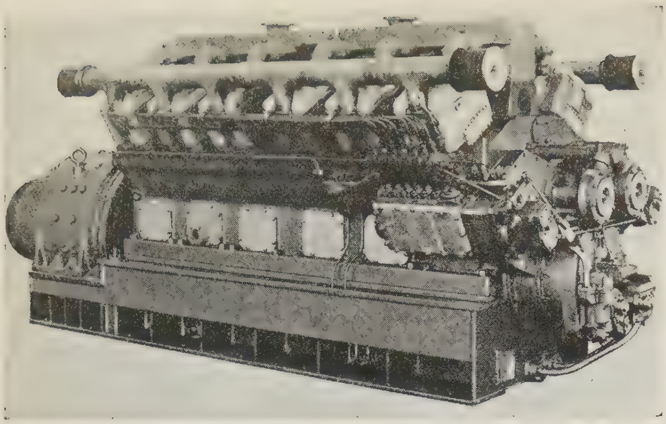

Fig. 6. A Diesel engine rated 800 horsepower, 900 rpm, 4 cycles, and having 12 9 by 12 inch cylinders

used at 15 miles per hour should be 75 per cent of the calculated value.

Development of High Speed Streamlined Trains

Within the last 4 years, the Diesel engine has been given serious consideration by the railroads. It has proved its effectiveness as a source of motive power and has demonstrated that it will actually reduce operating expenses both in rail car work and in switching work. The trend of the times has also been conducive to its adoption, especially in rail car work. A period of industrial stagnation always brings out radical ideas of all kinds, both politically and mechanically. New steels have been perfected; new methods of fabrication have been developed. New ideas of all kinds are rampant. The growth of air passenger traffic, even during the depression, has focused the attention of the public on aerodynamic construction to such an extent that even automobiles have suffered. Nevertheless, the airplane has had its effect on railroad train construction. The public preference for fast service, as evidenced by the air traffic growth and the stepping up of automobile speeds (40 miles per hour was fast road driving in 1925) has led some of the railroads to the conclusion that the provision of fast train service would be welcome, especially from Chicago to the western cities. Consideration of such fast trains led to the adoption of light weight construction, streamlining, articulation and the Diesel engine, since these features bring the power requirements down within the range of present engine construction.

The development of the modern streamlined passenger train may be definitely traced to rubber tires. The Michelin tire, as brought out in France for rail purposes and later tried in this country, necessitated light weight car construction. To construct such light weight cars, a new method of steel fabrication was developed in this country. With the increase in car weights and the consequent abandoning of rubber tires, the new fabrication methods were retained. This experience in light weight construction and reduced cross sections of cars pointed the way for further combination of such construction and aerodynamic lines, which puts the power requirements, even for high speeds, within the range of Diesel engine capacities. Thus, the so-called high speed streamlined trains which have been operated or are on order, are Diesel engine driven. As a matter of fact, increases in speeds of railroad trains are not as much a function of light weight construction and streamlining as of grades, curves, and traffic hazards. The only difference between a light weight, streamlined train and a conventional train is in the amount of power required for propulsion, and the present steam motive power is adequate to pull any normal train at as high a speed as these limitations will allow. Such spectacular runs as have been made with this new type of train have been under conditions which could not be tolerated for everyday railroading.

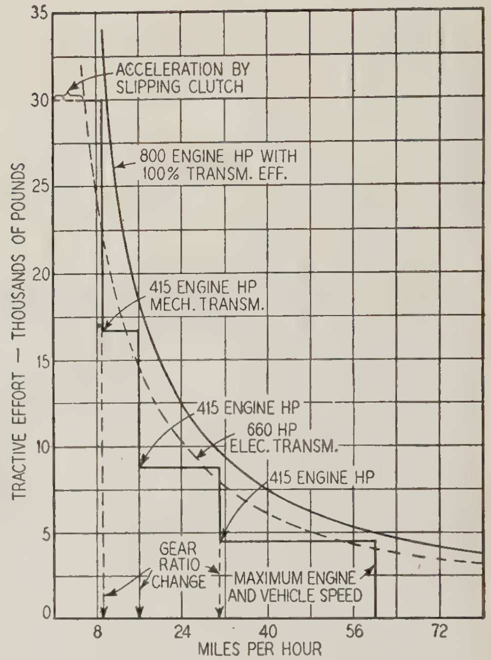

Fig. 7. Speed-tractive effort characteristics of mechanical transmission with 800 engine horsepower

There is no doubt but that the railroads as a whole will benefit by the construction and operation of such radical designs. For the past 10 years, they have been becoming weight-conscious, and are striving to decrease dead weights of rolling stock as compared to pay loads. The rapid development of new materials and methods of fabrication of such steels and aluminum for railroad cars will undoubtedly have its effect on future construction of conventional equipment.

Diesel Engine Capacities and Speeds

As has been pointed out before, the first Diesel locomotives were built with 300 horsepower engines. As has been the experience with all automotive developments, engine capacities have been rapidly increasing. Where the railroads originally bought locomotives of this capacity, they now want 600 to

900 horsepower for switching work, and even greater power for transfer service. Locomotives are on order up to 2,000 horsepower. It still takes 2 such locomotives to equal the performance of a modern 4-8-4 steam unit such as the railroads are now buying, and the first cost of 2 such locomotives cannot be justified by the operating savings, except in a few places. The Diesel designer, however, is striving vigorously to reduce manufacturing costs and, as these costs come down, the field of application will expand.

The manufacture of Diesel engines for railroad motive power is an accomplished fact. Much progress has been made since 1920—from the days when Diesel manufacturers thought that 250 rpm was a high engine speed, and some of the bolder of the conventional designers actually felt that it was possible to go to 350 or 375 rpm. Fundamentally, the success of the Diesel engine as a prime mover for railroad propulsion depends upon building within railroad clearance limitations, and to build large powers into these dimensions automatically dictates high engine speeds. The experience with the Diesel engine at 900 revolutions per minute has dispelled many of the supposed bugaboos of high engine speeds, with the result that most builders of railway Diesels are stepping up their speeds. Development of larger sizes beyond those considered possible at the present time may be expected in the future.

Three typical modern Diesel engines are shown in figures 1, 5, and 6.

Transmission Systems

The transmission of power from a prime mover to the wheels of a locomotive or rail car has been the subject of a great amount of thought. Mechanical transmission from reciprocating steam engines is simple, and has been proved to be practical and reliable. Transmission of power from internal combustion engines, however, is not as simple, since the prime mover cannot develop torque at zero speed. Among the systems proposed and tried are:

Mechanical drive (clutches, change gears, universal joints, etc.).
Hydraulic transmissions.
Pneumatic drives.
Electric transmissions.

The apparent simplicity of the mechanical system gave it an advantage during the early stages of self propelled rail car and locomotive development. With the gradual increase in engine sizes and train

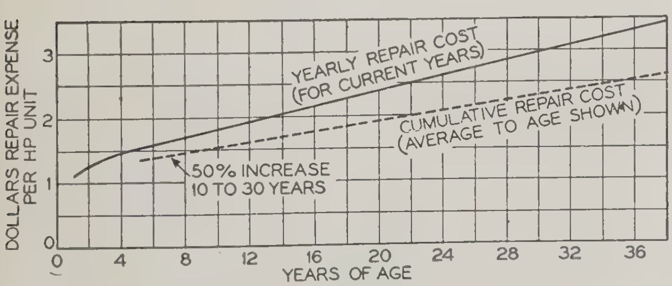

Fig. 8. Trend curves of repair cost for steam locomotive in switching service

weights, every opportunity was afforded to develop such transmissions, and, as an actual fact, they were used with some success up to 175 horsepower engine sizes. In spite of the intensive development, such transmissions have not persisted in the larger engine capacities, and nothing spectacular has appeared to date to show a reasonable expectancy of results better than have already been found.

Mechanical transmission involves a number of problems which have not, as yet, been successfully solved for large horsepowers (above 150 horsepower) and which are troublesome in even lower horsepower. These troubles include:

1. Transmission from a spring borne body to a swivel truck.

2. Transmission to an axle, one end of which may move up or down (with rail joint depression, etc.), and which has some lateral movement in the truck, as well as longitudinal movement in the journal box guides.

3. Engine mounting on the truck to reduce the problems of (1), results in high engine maintenance.

4. Gear shift transmission results in poor utilization of available engine power. Thus, each time the gear ratio is changed, power must be completely removed and engine speed dropped to approximately half speed (and half horsepower), following which the engine must accelerate the load to regain full horsepower. This is often impractical with varying railroad grades and results in long operation in an uneconomical gear ratio. This is shown by figure 7.

In spite of numerous attempts to use it, no hydraulic transmission has yet been found adequate for railroad service. The main difficulties are due to low efficiency, high maintenance, oil leakage, and emulsification of the oil.

There have been numerous attempts to employ compressed air for power transmission purposes. The fact that these attempts have resulted in no extended use of this system speaks for itself. Other freak drives (such as combinations of steam and Diesel drives) have not as yet attained a commercial status.

The only satisfactory system of power transmission for internal combustion engine rail motive power is the electric system. The reasons for this are:

1. Low maintenance costs as compared to other transmission.
2. Less physical labor for enginemen in control.
3. Greater over-all efficiency and engine power utilization.
4. Maximum tractive efforts and maximum speeds not a function of the engine.
5. Simple to apply power to multiplicity of driving axles.
6. Operation of auxiliary apparatus is simple.
7. Double end or multiple unit control is simple.
8. Power plant may be located in the most advantageous position.
9. Every engine has one or more critical speeds. These may be avoided by electrical transmission.
10. Experience has proved the economy and reliability of this system.

Trends in Repair Costs

It has been shown by tables I and II that Diesel car and switching locomotive operations result in savings over steam operation. One of the major savings which appear is that of repair expense. The railroads and some steam locomotive builders are

prone to discredit this saving in view of the lack of sufficient years of operation of the Diesels. The Diesel engineer, however, has considerable justification for the figures used and can point with certainty toward the future maintenance expense.

It has been demonstrated (and widely discussed) that there is a definitely rising repair expense trend for steam locomotives as their age increases. Figure 8 shows this steam locomotive trend. It may be expected that all machinery has a rising repair expense with age, the only undetermined factor being the rate of rise. An analysis of the 1932 report of the American Railway Association, committee on locomotive construction, and of the 1932 report of the heavy traction committee of the American Electric Railway Association has given a definite indication of this rate of rise for Diesel locomotives. In addition, a detailed analysis has been made by a competent railroad engineering officer, based upon Diesel operation on his own railroad, taking each piece of equipment in the complete locomotive and establishing its life, cost, and the labor required to replace the worn part. These trend curves are shown by figure 9. As a matter of fact, it is believed from electric locomotive experience and from gas car operation, that the curve will take quite a drop as operating experience piles up.

In closing, it should be emphasized that from the very beginning of railroads until early in the twentieth century, there was only one commercial source of mobile railroad motive power—steam. Now there are 2—steam, and the internal combustion engine. The rapid development which has taken place in the latter type since the introduction of the Diesel engine as a rail prime mover augurs well for this new method of power generation. The importance of the most modern Diesel developments in light weights and streamlining may be discounted as being the result of an industrial recession and as being limited in application, although the pioneering

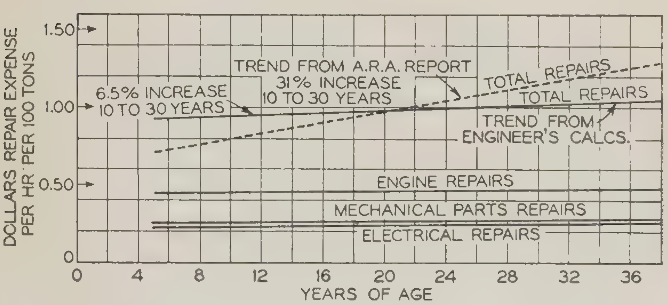

Fig. 9. Trend curves of repair cost for Diesel electric locomotive in switching service

work in weight reduction should have a far reaching effect on railroad cars of all kinds. The ultimate rail car will undoubtedly be of a conventional type, but of lighter construction as a result of the streamlined train experience. The immediate field for the Diesel engine is in switcher and transfer locomotives, with a gradual expansion into the road locomotive field as the economies become better established.

Spark Lag of the Sphere Gap

Measurements of time lag of spark-over of small sphere gaps at 3,820 volts were made with an instrument developed specifically for the purpose. Spark lags were found to fall into 3 distinct domains: 1 of relatively long initiatory lags of random distribution, and 2 of definite formative lags of different orders of magnitude corresponding to 2 different spark-over mechanisms. The controlling conditions which determine into which domain the spark lag will fall are given. The manner in which this lag may obscure the sparking voltage of the gap is pointed out and a remedial specification suggested. The results are applicable to larger sphere gaps and higher voltages.

By
ABE TILLES
ASSOCIATE A.I.E.E.

Univ. of California,
Berkeley.

IN the great majority of the investigations concerned with spark-over, the principal dependent variable under observation has been, naturally enough, the voltage at which the spark breakdown commenced. The time interval during which this voltage needs to act in order to initiate the spark-over has received, in comparison, only slight attention. This interval, the time lag of spark-over, or more briefly, the spark lag, is defined as the time interval during which a spark gap sustains a voltage greater than its minimum sparking voltage. Only recently, indeed, one may say with some precision, only within the last decade, has the time lag of spark-over been extensively investigated.

On the one hand, the theoretical predictions by Rogowski[12] and Loeb[8,9] of spark lags of the order 10^{-4} seconds stimulated research in this field. Zuber[17] and von Laue,[16] had established that for weak external ionization at low overvoltage the spark lags were rather long, *e. g.*, one second, and of erratic durations randomly distributed. Beams,[4] and Buss and Masch,[5] found at very high overvoltage an extremely brief formative spark lag, *e. g.*,

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12. For all numbered references, see list at end of paper.

2×10^{-8} seconds. Much work related to these theoretical problems was done in small gaps with initially uniform field and sparking voltages below 5,000 volts.

At the same time, spark lag was being studied in an entirely different connection and on an entirely different scale. The investigation of protection against brief lightning surges with their special wave form added the very greatest practical interest to the study of spark lags. Thus, just 10 years ago, McEachron and Wade[10] first co-ordinated the use at "full scale" voltages of 2 important instruments, the surge generator and the cathode ray oscillograph, which have been fruitfully utilized since. Torok,[14] by the ingenious method of "suppressed discharges," made visual observations of the incipient spark at approximately timed stages. Torok and Ramberg[15] more recently made a thoroughgoing comparison of the time lag of spark-over of insulator strings and of various arcing rings. Only last year[1] has the influence of time lag and wave shape been successfully included in writing test specifications for impulse spark-over, so that different laboratories can obtain comparable results at *this wave shape*, i. e., simulating lightning. Thus, engineering development had produced empirical information in many instances but had not yet led to any comprehensive classification of time lags of spark-over.

In particular, the relationship between the long, random, initiatory time lags observed at low external ionizations and the short formative lags observed at high external ionizations had never been clearly demonstrated by an experimental transition from one to the other. Further, the formative spark lags of static spark-over, i. e., of spark-over at low overvoltages, had never been ascertained. By means of a new timing instrument, these important measurements have been made. In conjunction with the previous literature of the subject, spark lags of the sphere gap are comprehensively classified and the spark-over mechanisms involved are made clear.

Conclusions

The conclusions drawn as a result of the study described in the present paper may be summarized as follows:

1. An instrument has been developed capable of measuring time lag of spark-over independently of lag variability and independently of voltage wave shape and magnitude.

2. Spark lags of the sphere gap were found to fall into 3 distinct domains.

3. In the first domain, i. e., with weak external ionization, the spark lags are long and of random distribution. The average lag increases greatly as the external ionizing source is weakened or the overvoltage decreased. The lags are primarily initiatory, i. e., spent in awaiting the arrival of electrons suitable to commence the spark-over process.

4. In the second domain, i. e., with adequate ionization and low overvoltage in a short gap, the lags are distributed about a definite value. The lags are primarily formative, i. e., represent the time required for the spark-over process to proceed to completion, i. e., to the point at which the gap voltage drops. The lags are of the general order of time required for a positive ion to cross the gap and assist in building up a space charge gradient.

5. In the third domain, i. e., with adequate ionization and a higher overvoltage or longer gap, the lags are also formative and of a definite value. Their magnitude is of the order of time required for a single electron avalanche to cross the gap.

6. The random initiatory lag contributes to the erratic performance of the sphere gap voltmeter.

7. This source of error should be eliminated by specifying an adequate ionizing source subsequent upon further practical experimentation.

8. The comparatively long formative lag of small gaps at low overvoltage may prove of practical importance in design of ignition gaps, safety gaps, etc.

9. At impulse spark-over the time lags and the exact voltage wave shape enter equally with the voltage magnitudes in determining whether spark-over will ensue.

10. Because of the variety of combinations possible, any attempt at a comprehensive classification of spark lags of point gaps must await much additional experimental work.

The Timing Instrument

Although instruments for measuring short intervals were available, they were not suitable for the tests at hand. As is well known, the phenomenal development within the last decade of the cathode ray oscillograph and the electro-optical shutter now make it possible to measure phenomena occurring with extreme rapidity, *e. g.*, within 10^{-8} seconds. These excellent instruments, however, have a quite limited range. That is, they can only measure a time interval reasonably close to the full scale value for which they are just then adjusted. They are not, therefore, suitable to measure successive individual time lags, one of which, for instance, is 10^{-5} seconds and the next 1 second. Furthermore, for statistical distributions requiring large numbers of readings the expense and delay of photographic readings rather than direct indications becomes seriously objectionable. It was necessary to have an instrument which:

1. Could measure quite brief time intervals (*e. g.*, in these particular tests 10^{-5} seconds).

2. Stood ready to measure *individual* lags from the minimum reading of the instrument up to any longer interval.

3. Could await the application of the sparking voltage for an indefinite length of time.

4. Could be adjusted with extreme precision as to the minimum sparking voltage above which it was to respond critically.

5. Would measure the duration of overvoltage independently of the magnitude, wave shape, or method of application, of the voltage.

6. Gave direct readings.

These stringent requirements were met by a vacuum tube circuit which might be called an incremental-voltage amplifier, since its action depends on the high amplification of the first increment of overvoltage. The circuit is shown in figure 1. Briefly, the first tube is an inverted vacuum tube voltmeter, drawing no power from the test gap and reducing the voltage to a value convenient to work with. Its output, in series with an adjustable bias, is brought to the second tube. The second and third tubes provide a high linear amplification, which swings the grid of the fourth tube from a substantial negative voltage to a substantial positive voltage as the gap voltage is rising a small increment past the value for which the bias is adjusted. The output of the fourth tube is thereby raised from zero to a

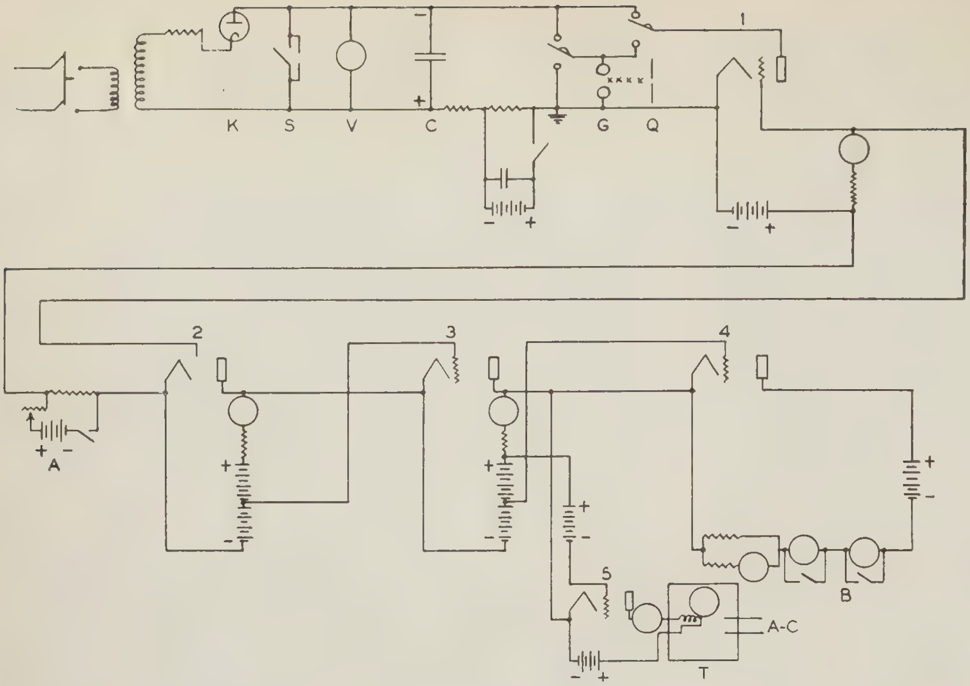


Fig. 1. An instrument for spark lag measurements

K—A 2-electrode vacuum rectifier tube
S—Safety gap and discharge switch
V—Electrostatic voltmeter
C—Storage condenser
G—Test gap
Q—Quartz mercury arc
A—Bias adjustment
T—Synchronous timer
B—Ballistic galvanometer

Tube	"B" Supply Voltage	Output Circuit Resistor
1—OM5	156	1.92 megohms
2—CX340	180	0.5 megohms
3—CX345	180	0.1 megohms
4—CX340	90	0.25 megohms
5—CX345	180	500 ohms

constant maximum value (i. e., to the plate supply voltage divided by the external plate resistance). This current is passed through ballistic galvanometers whose throws are directly calibrated in seconds. As the bias is adjusted so that the critical response is at the minimum sparking potential of the gap, the galvanometer reading gives directly the time interval that the gap voltage has remained above this minimum sparking voltage, i. e., the time lag of spark-over. The third tube also supplies another amplifier tube, which operates a synchronous timer that registers any longer interval. The plate currents of these tubes are calibrated and used to obtain a reading of the gap voltage.

Test Gap, Voltage, and Illumination

The spark gap used in these tests consisted of copper spheres of $^3/_4$ inch (1.904 centimeter) diameter and 0.0269 inch (0.0683 centimeter) spacing in dehydrated air at atmospheric pressure. The static sparking potential was 3,820 volts. A gap so small was used to afford a direct comparison with the "pure science" literature of the subject, and also, because of the greater economy and convenience of the lower voltage circuits. The results are entirely applicable to larger sphere gaps. Two voltage wave shapes were utilized, as shown in figure 2. The first approximated "static" spark-over; the main d-c voltage was set at 96 per cent of sparking voltage and a bank of "B" batteries was then thrown across a resistance in the circuit to raise the gap voltage suddenly to a constant value some per cent above the sparking voltage. The second wave shape, constant d-c voltage suddenly applied, approximated "impulse" spark-over but at small overvoltages. Both wave shapes were quite rectangular, the time of rise of the voltage and also the time of voltage drop each being very much less (*e. g.*, $^1/_{1,000}$) than the shortest time lags being measured. Photoelectric ionization was produced by illuminating the gap with ultra-violet light of measured intensity from a quartz mercury lamp.

The Random Distribution

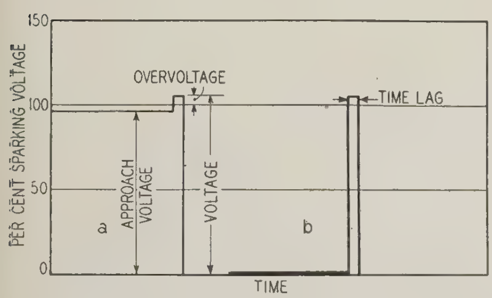
Many of the test series resulted in random distributions. Accordingly, it might be well at this point to say that a random distribution is a quite definite thing, and also to explain the method of plotting it. A series of time intervals, in this case spark lags, may be defined as having a random duration if each one is as likely to be terminated during any one time increment as during any other equal increment. The *constant* probability of its termination within a unit time increment may then be denoted by p. Hence, it can be easily shown[16] that a series of such random spark lags must fit the equation $n_t = 100\epsilon^{-pt}$ wherein n_t is the percentage of the total number of lags which is as great as or greater than t. The average time lag $T = 1/p$. Note that for $t = T$, $n_t = 100\epsilon^{-1}$ or $n_t = 36.8$ per cent. That is, most of the lags are shorter than average, only 36.8 per cent being longer; of these, however, a few are much longer, thus striking an average.

In plotting the data the series of spark lags are arranged and numbered in order of magnitude and this order number is then divided by the total number of spark lags in the series and multiplied by 100, thus giving each lag a per cent order of magnitude designation. This per cent order of magnitude is then plotted against its corresponding time lag interval, giving points on a curve of n_t against t. Each spark-over measured contributes one point to the curve. These are joined by light lines, the lower left hand corners of the light curves being the actual data points. The resultant curve is then placed so that the number of points above it equals the number below. Where the distribution is truly random, the curve obtained is a simple exponential

or, if plotted on semi-logarithmic paper, a straight line. The ordinate of any point on the curve gives the percentage of the total number of spark lags of the series which are as great as, or greater than, the time interval given by its abscissa.

Test Data

At each illumination a series of spark lag measurements was made for each of several voltages in the neighborhood of 105 per cent. This whole group of measurements was then repeated at other illuminations. The reader's inspection of the data here presented will perhaps be assisted by a brief qualitative statement of the results. At low illumination the spark lag distribution is random as shown by the straight line distribution curves obtained on semi-logarithmic paper; increasing the voltage decreases the lag duration generally, giving a similar but steeper distribution curve. Until a certain point, increasing the illumination, likewise, merely steepens the distribution curve. At higher illuminations, however, a transitional distribution appears wherein a fraction of the observed lags have a random distribution similar to those already mentioned and the remainder have an entirely different type of distribution. As the illumination is further increased a larger fraction of the lags fits the second distribution, and for all adequately intense illuminations all the lags fit the second type of distribution. This is a highly peaked distribution containing a few large and many small deviations from a single definite value. In fact, some 40 per cent of all the lags observed are of practically identical duration. These results are illustrated by the selected curves of figures 3 and 4.



a—"Static" spark-over
b—"Impulse" spark-over
The actual time for the voltage changes which are drawn vertically is about 1/1000 of the smallest spark lags measured

Fig. 2. Voltage wave shapes

Figure 3*a* shows 3 curves of spark lag distribution at static spark-over at 3 different voltages and at 1 intensity of initial ionization. This intensity is measured by measuring the saturation current *I*, in micromicroamperes per square centimeter, ejected from a plate of clean nickel in vacuum by the ultraviolet illumination utilized. For this one illumination the average time lag, obtained from the curves of figure 3*a*, is plotted against per cent overvoltage in figure 3*b*. It will be noted that this curve also is a simple exponential. The average lag at a specified overvoltage is readily obtained by interpolation from this curve for use on the master curve of figure 7. Figure 4 illustrates, for static spark-over near 105 per cent voltage, the change in type of spark lag distribution as the illumination is successively increased.

As mentioned, for the random distributions at low illumination the effect of small increases in voltage is merely to decrease the lags generally, giving a similar but steeper random distribution. At the intermediate illuminations with transitional distributions, increasing the voltage causes a greater proportion of total number of lags to fall into the peaked distribution. At the high illuminations with peaked distributions small changes in voltage do not alter the lag distribution. The entire test series was repeated for impulse spark-over, with highly similar results. These relationships may be observed in figures 5 and 6, which contain a major portion of the test data.

At each illumination a curve, such as figure 3*b*, of the average lag of the random distributions was plotted against overvoltage. For static spark-over these curves were all exponential over the range from 1 to 6 per cent overvoltage and all had nearly the same exponent. Thus, the factor by which v, the per cent overvoltage, modifies the average lag may be inclusively stated as $f(v) = \epsilon^{-(0.39\pm0.08)v}$. For impulse spark-over these curves deviated somewhat from simple exponentials but still fitted this same equation near 5 per cent overvoltage.

The average time lags of static spark-over at 105 per cent voltage, as interpolated from the above mentioned curves, are plotted against illumination in the master curve 1 of figure 7. The peak value of the peak distributions is also plotted against illumination in the second segment of curve 1. At the illumination giving the transitional distributions the 2 curve segments are shown dotted. As indicated, the 70

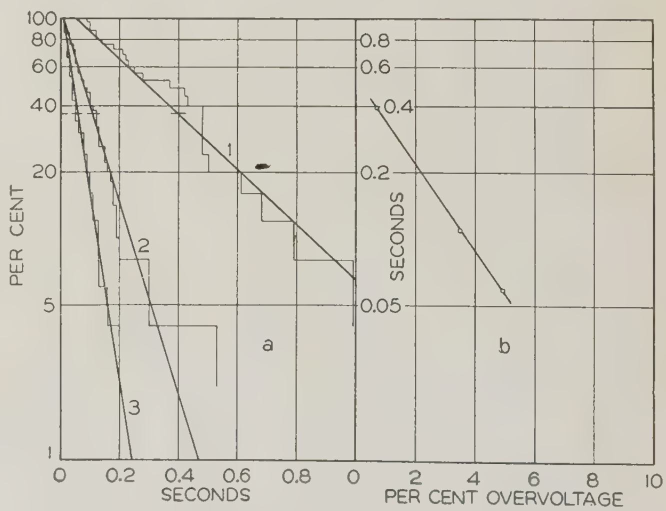


Fig. 3. Random spark lags at one illumination. I = 0.00183; approach voltage = 96 per cent

a—Spark lag distributions
Curve 1—Overvoltage = 0.7 per cent
Curve 2—Overvoltage = 3.5 per cent
Curve 3—Overvoltage = 4.9 per cent
The curve ordinate gives the percentage of lags which are greater than the time interval given by the abscissa
b—Average lag versus per cent overvoltage

per cent of the lags giving a random distribution have magnitudes fitting the curve for the all random distributions; likewise, the 30 per cent of the lags constituting the peaked distribution fit with the other peaked distributions. Master curve 2 of figure 7 is similarly plotted for static spark-over at 3 per cent overvoltage, and master curve 3 for impulse spark-over at 5 per cent overvoltage. These master curves show clearly how increasing the illumination decreases greatly the random lags, and how further increase in illumination gives rise to the lags of peaked distribution. The magnitude of the lags of the peaked distribution remains uninfluenced by a further 30-fold increase in the illumination. A better qualitative conception of the extent of these curves, for instance, curve 1, may perhaps be obtained by replotting a portion of it in figure 8 on ordinary graph paper. It is clear from curves 1 and 2, figure 7, that the small decrease in overvoltage from 5 per cent to 3 per cent more than doubles the random lags but leaves the peaked lags virtually unchanged.

Inspection of master curves 1 and 3 shows surprisingly little difference in the spark lags for static and impulse spark-over. Throughout the random lags those of static spark-over are less than half as big as those of impulse spark-over. Apparently the only effect of the 96 per cent approach voltage is, due to cumulative ionization by collision, to increase the general level of ionization at the gap.

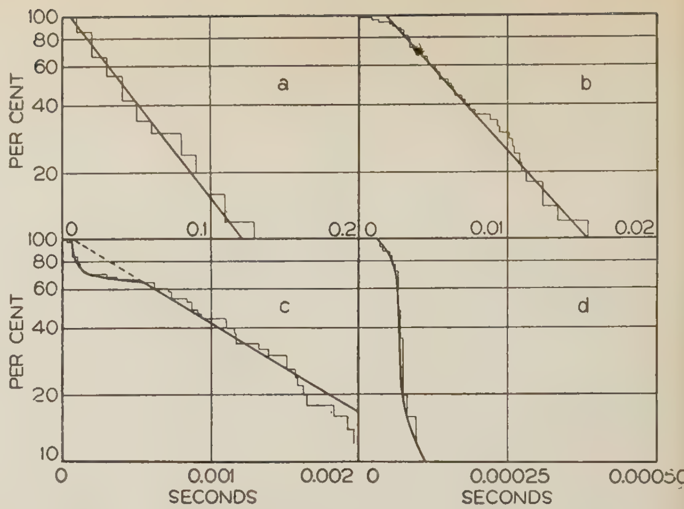


Fig. 4. Spark lag distributions for different illuminations

a—Random at I = 0.00183 c—Transitional at I = 0.365
b—Random at I = 0.0258 d—Peaked at I = 5.75
The curve ordinate gives the percentage of lags which are greater than the time interval given by the abscissa

Test Results

Quantitatively, the results of these tests may be summed up as follows. For this gap, for static spark-over, for illuminations from $I = 0.002$, the smallest studied, to $I = 0.5$ and for overvoltages from 1 per cent to 6 per cent the spark lags are random, fitting the distribution equation $n_t = 100\epsilon^{-pt}$, and the average lag is

$$1/p = T = 0.0037\epsilon^{-(0.39\pm 0.08)v}I^{-0.76}.$$

The central value of exponent is correct for $v = 5$ in every case. For impulse spark-over, as can be seen from figure 7, etc., the relationships are similar but not identical. The equation

$$1/p = T = 0.0078\epsilon^{-0.39n}I^{-0.76}.$$

is adequate from $I = 0.02$ to $I = 0.5$ and for $v = 5 \pm 1$.

Here

I = intensity of photoelectric illumination measured by the current in micromicroampere per square centimeter expelled from a clean nickel plate in vacuum
v = per cent overvoltage
T = average lag of a random distribution in seconds
ϵ = the base of Naperian logarithms
p = probability of a spark-over within a one-second time increment
n_t = the percentage of lags enduring a time t or more
t = time in seconds

For $I = 0.5$ there is a transitional distribution, 70 per cent of the spark-overs occuring in a distribution whose average exactly fits the above equations and 30 per cent fitting the peaked distributions. For successively larger illuminations a successively larger proportion of the lags fit the latter distribution.

From $I = 0.5$ to $I = 10$, the largest studied, for either of the voltage wave shapes studied and for overvoltages from 2 to 6 per cent, the lags have a highly peaked distribution, deviating but slightly from a definite central value. Throughout this region this central value remains $(0.70 \pm 0.15) \times 10^{-4}$ seconds, as theoretically predicted.[8]

From consideration of the literature,[4,5] in part supplemented by test, it is clear that at high overvoltages with adequate illumination the spark lag must have a brief definite value, *e. g.*, 10^{-8} seconds.

These are believed to be the first comprehensive experimental observations of the transition from the initiatory lags to the formative lags, and also, the first observations of the formative time of static spark-over.

The Nature of the Spark Lag

It is now possible to point out the nature of the spark lag. The time lag of spark-over in every case consists of an initiatory lag followed by a formative lag. Under appropriate conditions either of these may become entirely negligible in magnitude compared with the other. The initiatory lag is the elapsed time from the instant the sparking voltage is applied to the gap to the instant of arrival of suitable initiatory electrons which allow the voltage to commence the spark-over process. The formative lag is the time required for one or another of the spark-over processes to proceed to completion, i. e., to the point at which the gap voltage drops.

Spark lags are found to fall into 3 distinct domains. First, are found long initiatory lags (*e. g.*, 10^{+1} to 10^{-3} seconds) of random distribution spent in awaiting a favorable fortuitous space and time arrangement of the somewhat insufficient supply of initiatory electrons. Second, are found intermediate formative lags (of the order 10^{-4} seconds) distributed about a

definite peak value of the general order of time required for a positive ion to cross the gap and assist in building up a space charge gradient. Third, are found short formative lags (of the order 10^{-7} seconds) distributed about a definite peak value of the order of time required for an electron to cross the gap.

The controlling condition for the first domain is that the external ionizing forces be inadequate. Here the initiatory lag spent in awaiting the fortuitous arrival or creation of electrons so located as to be capable of commencing the spark-over is very much greater than the formative lag. Since this appearance of electrons is as likely at any one instant as at any other, being entirely haphazard with respect to the instant at which sparking voltage is applied to the gap, the distribution of these initiatory lags is truly random. Note that if the voltage is increased the volume within which an electron must appear in order to be effective in initiating spark-over obviously increases. Hence the average lag decreases. The initiatory lags may be extremely large if the external ionizing forces are small, but as these are sufficiently increased the entire initiatory lag becomes negligibly small and the formative lag of either domain 2 or 3, as the case may be, prevails.

The formative lags are observed to fall into the second domain when the prevalent conditions are least favorable to the effective formation of electron avalanches, i. e., when both the per cent overvoltage of the gap and its absolute length are small. The formative lags fall into the third domain when the conditions are made more favorable to cumulative ionization by electron collision, i. e., when the per cent overvoltage is increased or when, while using the same per cent overvoltage, the gap length or air pressure are increased. The exact boundaries of this transition have yet to be observed, but, judging by the work of Dunnington,[6] at overvoltages of the order of 0.5 per cent the second domain prevails for gaps less than 0.28 centimeter long and the third domain for gaps greater than this.

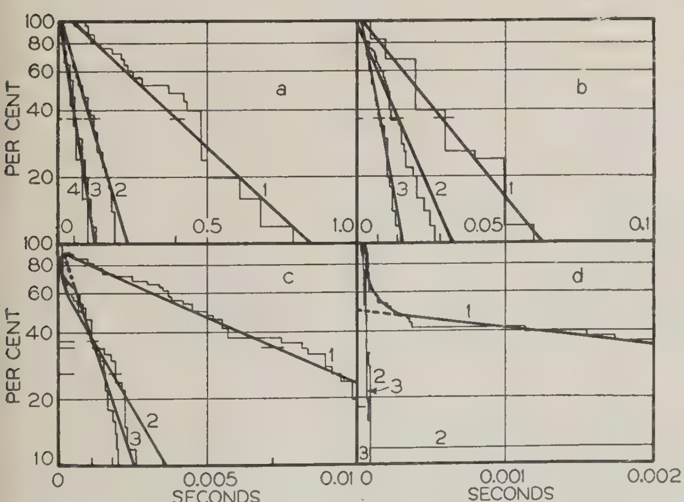


Fig. 5. Static spark lag

The curve ordinate gives the percentage of lags which are greater than the time interval given by the abscissa

Section	a	b	c	d
	0.00183	0.0258	0.365	5.75
Curve 1—% voltage	100.7	100.9	100.8	101.7
Curve 2—% voltage	103.5	103.5	103.8	104.2
Curve 3—% voltage	104.9	104.9	105.4	106.4
Curve 4—% voltage	105.9			

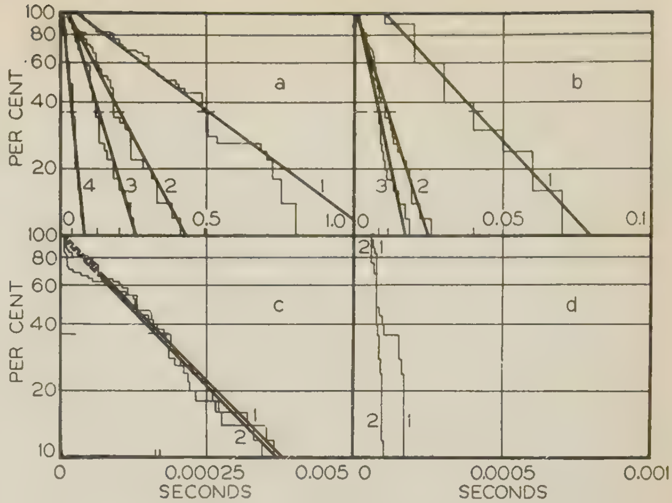


Fig. 6. Impulse spark lag

The curve ordinate gives the percentage of lags which are greater than the time interval given by the abscissa

Section	a	b	c	d
	0.00301	0.0536	0.600	9.80
Curve 1—% voltage	101.8	102.2	105.2	101.8
Curve 2—% voltage	105.2	104.6	107	104.9
Curve 3—% voltage	107.1	107		
Curve 4—% voltage	120.1			

The Spark-Over Mechanism

This difference in formative lag arises from a difference in spark-over mechanism which may be roughly described as follows. In domain 2 each initial electron avalanche leaves behind it a space charge formation whose density increases exponentially with distance from the cathode. This positive ion space charge travels across the gap into the cathode. As its most dense rear layer approaches the cathode it there produces the greatest voltage gradient which the entire phenomenon is capable of producing. This gradient being adequate, positive ion ionization ensues and spark-over is rapidly completed. The formative time in domain 2 must, therefore, allow for positive ion migration and the spark breakdown must commence at the cathode. For the conditions of domain 3 the exponential curve of positive ion density aforementioned, being steeper, produces a space potential gradient adequate for positive ion ionization at some point in mid gap *at once*, i. e., before the positive ions have migrated any appreciable distance. The flood of electrons released by this positive ion ionization arrives at the anode, starting the voltage drop, one step behind the initial avalanche, as it were. Thus, in domain 3 the formative time is that required for an electron to travel across the gap, and the spark-over commences in mid gap.

Direct visual observations of the incipient spark give striking verification that the spark may occur by 1 of these 2 distinct mechanisms. This was first observed, in a qualitative way, by Torok.[14] Torok found that for most of his tests the visual spark-over

began at the cathode. In a few tests on small gaps at high overvoltage Torok noted a distinctly different phenomenon; an intense white light at the middle of the gap was then the initial stage of the spark. Dunnington[6] used a Kerr cell, or electro-optical shutter, for visual observations of successive stages of spark-over at precisely timed intervals. His observations at various pressures and gap lengths and at small overvoltages, established these 2 types of spark-over, i. e., 1 in which the visible spark is seen to initiate exclusively at the cathode, and a second, in which the spark is seen to commence somewhere in mid gap.

It is particularly gratifying that, in the light of the above explanations, the various available reports in this rapidly developing subject of spark lags are seen to be consistent with each other and with a rational spark-over mechanism, whereas, hitherto, they had appeared isolated and even contradictory. This correlation, as well as a more detailed discussion of the spark mechanism, is available elsewhere.[13]

Engineering Applications

The points of engineering interest to which the foregoing information on the time lag of the sphere gap is applicable are too numerous to be more than mentioned. The magnitude of the initiatory spark lags of domain one undergoes the widest variation under varying conditions and may, therefore, often be great enough to be of serious consequence. By way of orientation it may be pointed out that "ordinary" open air contains per cubic centimeter on the order of 1,000 pairs of ions, and has formed in it each second about 10 new electrons by action of cosmic rays, atmospherics, radioactive minerals, etc. These 10 new electrons per second per cubic centimeter near the surface of the cathode sphere at the axis of the gap may be considered as a very rough "average" external ionization. (Small spheres, therefore, receive less ionization, having less cathode area.) Of course, this rate of ionization varies widely with locality and with atmospheric and stellar conditions. It will be increased by the proximity of high voltage equipment or of radioactive minerals and decreased by metal enclosures. Thus, within 7 centimeters of lead this ionization rate is reduced to the order of once every 20 minutes.[3] The external ionization at a small test gap can be increased by the use of radioactive salts, X rays, or ultra-violet illumination. The photoelectric emissivity of the cathode may vary greatly with slight changes in surface condition, such as adhesion of vaporous impurities, oxidation caused by successive power spark-overs, etc.

The Sphere Gap Voltmeter

Obviously, one of the important practical effects of spark lag is its modification of the apparent sparking voltage as measured by the sphere gap voltmeter. This will be different for different voltage wave shapes. For static spark-over, i. e., either d-c or 60 cycle a-c voltage gradients increased slowly and continuously until spark-over, the formative lags are too brief to be of any consequence. The random initiatory lags, however, may well be long enough so that the increase in voltage gradient has proceeded a perceptible amount past the minimum sparking gradient while awaiting the arrival of suitable initiatory electrons. In that case, when spark-over does occur, it occurs at a small overvoltage which is then mistakenly supposed to be the minimum sparking voltage of the gap. Of course, this source of error may be empirically eliminated by finding a rate of voltage increase, or of gap shortening, which is slow enough so that smooth calibration curves are obtained. Thus the present Standards[2] of the Institute specify a rate of voltage increase not to exceed 50 per cent of sparking voltage per 30 seconds.

There have been difficulties in applying this empirical precaution, however, as evidenced by the fact that erratic results have not always been avoided. One difficulty is, perhaps, merely that human patience was being pitted against an unsuspectedly erratic delay and, therefore, quite naturally arrived at a degree of deliberateness sufficient to outwait most of the delays encountered but not all of them. A more formidable difficulty is that the external sources of ionization may, as is evident from perusal of the preceding paragraph, on certain occasions be much weaker than at the time and place when the erstwhile satisfactory test procedure was being empirically established. As long as the source of initiatory electrons is left, as is the case at present, entirely unspecified and may be chiefly haphazard atmospherics, etc., the random lag may change 10,000 fold in the same laboratory from one day to the next.

The resultant erratic behavior of the gap can, perhaps, be best ameliorated by specifying a standard and fairly strong source of ultra-violet light and a cathode surface of sufficiently high emission characteristics. Concretely, consider the simply stated case of d-c spark-over. (The specification for a-c spark-over is just as definite but is less straightforward to state since it requires the coining of a definition for "a-c elapsed time lag.") With the present specified voltage increase rate of 1.66 per cent per second, errors can be limited, for instance, to less than 0.83 per cent *in 95 per cent of the spark-overs* by choosing a value of external ionization probability such that, at overvoltages as low as 0.415 per cent, only 5 per cent of the initiatory spark lags are greater than 0.25 second. That is, $n_t = 100\epsilon^{-pt}$ becomes $5 = 100\epsilon^{-p0.25}$, from which is ob-

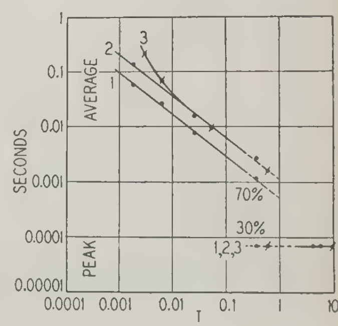


Fig. 7. Time lag of spark-over versus illumination

Master curve of average or peak values

Curve	Approach	Voltage
1	96%	105%
2	96%	103%
3	0%	105%

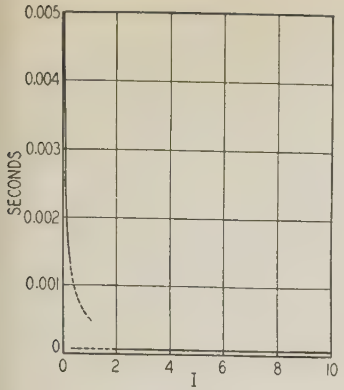


Fig. 8. Static spark lag versus illumination

tained $p = 12$ or $T = 1/p = {}^1/_{12}$ second. Hence, to insure this degree of accuracy it is necessary to specify an external ionizing source of sufficient strength to produce an average time lag of static spark-over at 0.415 per cent overvoltage of ${}^1/_{12}$ second. Otherwise stated, it is necessary to specify a source which produces 12 times a second, on the average, initiatory electrons *at those portions of the gap* where they can initiate spark-over at overvoltages as low as 0.415 per cent. Before such a standard can be practically specified, measurements of time lag of static spark-over must be taken on high voltage gaps whose electrode surfaces are modified by the high power sparks and arcs they sustain and by the subsequent cleansing operations. This is an important division of the subject that appears to be entirely untouched as yet.

For high frequency steady state static spark-over the initiatory lags enter much as for low frequency. In addition, the space charge migration times, which are essentially formative lags in the second domain, systematically modify the voltage magnitude required for spark-over. This has been thoroughly established by Reukema.[11]

The formative lags of the second domain are of practical importance, also, wherever very small gaps are used; for it is no small matter that very small sphere gaps break down by a different and slower process than larger ones. Small gaps are widely utilized for duties wherein a rapid breakdown is desirable, *e. g.*, ignition spark plugs, telephone plant protective gaps, etc. The fact that such gaps have an irreducible spark lag of the order 10^{-4} seconds at their minimum sparking potential and a lag less than ${}^1/_{1,000}$ as great at some definitely predictable overvoltage would appear to be of practical interest. A typical 9 cylinder aircraft engine going 2,000 rpm, travels 1.2 mechanical degrees or 5.4 electrical degrees in 10^{-4} seconds, and the voltage wave of a magneto rises for only a few degrees. A surge on an open wire line travels over 18 miles in 10^{-4} seconds. This time interval is not negligible. It is not intended to imply that empirical design in these various matters has been inadequate; merely, that more complete theoretical comprehension is likely to lead to improvement.

For impulse voltages or for any transient voltage wave shape of very brief duration, the brief formative lags of domain 3 are of importance. For such voltages it is now well appreciated that the time lags involved and the exact voltage wave shape enter equally with the voltage magnitudes in determining whether spark-over will ensue. To produce spark-over, either some overvoltage must exist for a time equal to the initiatory lag plus the formative lag of domain 2, or else an overvoltage sufficiently high to give the spark-over of domain 3 must exist for a time equal to the initiatory lag plus the shorter formative lag of domain 3. If the voltage rises with sufficient rapidity it can become sufficiently high before the charged particles originally in the gap are swept out. In this case these can act as the initiatory ions, thus reducing the initiatory lag practically to the vanishing point. As mentioned, recent test specifications for impulse testing now make it possible to obtain consistent results at this wave shape, i. e., simulating lightning. Considering the confusion prevailing on this point until now, as pointed out by the Institute's sub-committee on lightning,[1] engineers may be warned and realize the desirability of studying the time factors involved in various other spark-over problems of interest.

The Point Gap

Throughout this paper the spark lag of the sphere gap at spacings fairly small compared to the sphere diameter, i. e., of a gap with an initially uniform field, has been under consideration. In practice, many spark-overs, both desired and undesired, occur at what is essentially a point to point gap with initially nonuniform field. A few brief remarks concerning spark lags of such gaps may, therefore, not be amiss. It seems clear that the time lag of spark-over in a long gap must be built up of the items already mentioned. Just as in the short gap, there are initiatory lags. Where there is preliminary corona the initiatory lags will be greatly decreased, even to the vanishing point. Moisture in the gap captures free electrons and increases the initiatory lag. Moisture on the electrode, as recently shown by Hillebrand and Miller,[7] gives in effect a water electrode, and this tends to decrease the initiatory lag.

There are formative lags spent in awaiting the mass motion of positive ions toward the cathode or, depending upon the voltage gradient, formative lags spent in awaiting the passage of an electron avalanche. The possible time and space combinations of these 2 formative mechanisms allow an almost unlimited number of combinations in long gaps of various geometries. It is clear, therefore, that the time lags of point gaps will not lend themselves to any comprehensive classification without a great amount of additional experimental work.

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Registration of Engineers

By D. B. STEINMAN,* Member A.S.C.E.
Consulting Engineer, New York, N. Y.

Following is the full text of an address presented at the A.I.E.E. summer convention, Ithaca, N. Y., June 24–28, 1935, and prepared at the request of the A.I.E.E. committee on education, in order that the membership might be more fully informed concerning engineers' registration and the related problems of the profession, and may determine to what extent the arguments for registration apply to electrical engineers, whether engaged in practice for themselves or employed by others, and whether engaged on private or public work.

ENGINEERS are pioneers, pathfinders, trail blazers in almost everything they do, with one exception. They have left it to the other professions to be the pioneers and trail blazers in the field of securing professional recognition, in the field of organizational and legislative activities for the advancement of the status of a profession. The medical profession started over 80 years ago, the legal profession over 50 years ago, but the engineering profession is just commencing to direct its planned activity to the problems of professional standing and recognition.

We are fortunate that others have blazed the trail and that other professions have solved for us many of the problems involved. If there is any wisdom in the collective mind of the engineers of the country, we will lose no time in profiting by the successful examples of the professions that have solved these problems before us; and the first essential step in such program is the enactment of laws establishing qualification standards for the practice of the profession.

Progress of Registration

Engineers' registration laws are now in force in 32 states. In these 32 states are located over 85 per cent of the engineers of this country. In addition to these states, the 3 possessions of the United States—Hawaii, Puerto Rico, and the Philippines—also have engineers' registration laws. The progress of enactment of engineers' registration laws dates from Wyoming in 1907 and New York in 1920 to Ohio in 1933 and New Mexico, Washington, Utah, Maine, and Oklahoma in 1935. More states are being added to the list progressively. Such legislation is now pending in 11 additional states, leaving only 5 states (of small engineering population) in which the profession has not yet decided to advance the registration movement. With the active impetus given to the movement by the National Society of Professional Engineers, more rapid progress now may be expected in extending registration to cover the remaining states.

Over 45,000 engineers have already been registered in 31 states: over 12,000 in New York State, over 6,000 in California, and over 4,000 in Pennsylvania. Engineers' registration is now an established fact, and it is here to stay.

The Philosophy of Registration

The underlying philosophy of registration laws has been aptly expressed by Arthur V. Sheridan, past president of the New York State Society of Professional Engineers:

"Regulation of human activities is a sine qua non of civilization. Without it chaos would be the concomitant of communal existence. There are, of

* Chairman, New York State Board of Examiners for Professional Engineers; past-president, National Council of State Boards of Engineering Examiners; and president, National Society of Professional Engineers.

course, limitations, for even regulation does not justify servitude. Throughout the ages philosophers have debated the ability of mankind to direct itself adequately. Regardless, however, of academic disputations the fact remains that society cannot avoid the responsibilities arising from the gregarious instincts of human beings.

"Modern civilization, the creation of the engineer, has found it necessary to regulate the practices of persons whose activities deal with the protection of human life, human health, human rights, and human property.

"Three professions, law, medicine, and engineering are primarily entrusted with the responsibility incidental to such activities. The elimination and exclusion, as matters of public welfare, of the dishonest and unqualified from the practice of these professions are undebatable tenets. It is to the accomplishment of such aims that truly professional associations are dedicated."

The Public Aspect of Registration

Engineers' registration is required for the protection of the public. The work of no other profession more truly concerns the safety of life, health, and property. There is a public demand for this legislation, and we owe it to the public and to our profession to take the initiative. We do not want the legislation to be thrust upon us. Being fully conversant with the problems involved, we want to have a hand in writing the law, in securing its enactment, and in directing its administration, as a recognition of our responsibility, as a profession, to the public.

The public needs to be protected against the quack, the incompetent, the unscrupulous, and the impostor, who do not belong in our profession but nevertheless practice in its name. The investor needs to be protected against "engineering" reports by the unqualified and the unscrupulous. The client needs to be protected against paying fees to quacks and incompetents who hold themselves out as "engineers." The courts need to be protected against the testimony of "experts" who pose as members of our profession. The public needs to be protected against improper planning, inefficient design, wasteful execution, and excessive cost, also against dishonorable dealings. Mere structural adequacy is not the only desideratum.

Protection of the public is the legislative justification and establishes constitutionality. This benefit has been established. Protection of the profession, its standing and its standards, is a concomitant benefit. The 2 benefits are inseparable. The elimination of the unqualified and the unworthy benefits both the public and the profession.

Professional Aspects of Registration

Engineers' registration laws derive their primary justification from considerations of public safety and the protection of public interest; but they are also necessary for the protection of the good name of the profession and its standing in public confidence.

A profession is judged by the qualifications of all who use its name, by the failures of the incompetents and by the conduct of the unworthy, unless a clear dividing line is established in public recognition between the lawful practitioners of the profession and those who are not admitted to practice.

A profession should be empowered to disown those who hold themselves out as belonging to it without proper qualifications or character and to bar the unfit and the unprincipled who seek to practice in its name. The public expects a trusted profession to maintain high standards of qualification and to clear its ranks of those who do not meet those standards and whose pretensions and activities would degrade its good name.

Without registration laws, there is no way: (1) to stop the practice of engineering by the nonengineer; (2) to stop the misappropriation and abuse of the designation "engineer"; (3) to oust from the profession those who prove incompetent and unworthy; and (4) to preserve to the qualified engineer his rights of practice against restriction, encroachment, and unqualified competition.

Registration places the force and sanction of the law behind the desire of the profession to maintain a clearly recognizable line of demarcation between the engineer and the nonengineer. It places the agencies of the law behind the efforts and aspirations of the profession to maintain high standards of qualifications and ethical practice.

Registration and Public Recognition

Registration places engineering on a par with law and medicine as legally restricted and recognized learned professions. With the aid of the registration laws that have come into being in our statute books, the engineering profession has made more real progress in the past 10 years in the solution of many of its problems and in securing public recognition than in all the decades preceding.

The other learned professions, such as law and medicine, have long had laws in all the states regulating professional admission and practice. Public respect and confidence toward those professions have grown in proportion to the virility with which they have used their registration laws to maintain high standards and to eliminate the untrained and the unethical. Engineers' registration will accomplish the same objectives for our profession. It is an essential step in our program of securing for the engineering profession its rightful place in public confidence and respect.

We cannot expect the public to distinguish between the engineer and the artisan or mechanic, between the professional man and the impostor, and between the professionally trained and the half-trained or immature, unless we adopt the accepted and established procedure for legally qualifying and identifying the members of our profession. The public will not have proper regard for our profession unless we, ourselves, hold it in sufficient regard to exclude those whose practice or pretensions would degrade it. We cannot do these things without registration.

Protection of the Designation

A problem closely related to registration is that of protecting our professional designation.

The individual engineer has invested many years of his life in professional education and arduous professional training in order to qualify as an "engineer." The profession is investing decades of united effort to win public recognition and esteem for those who bear the title "engineer." All of this investment is largely nullified if the use of the term "engineer" is left unprotected. The dignity and respect that rightly belong to the designation of a learned profession cannot be maintained when that designation is abused by misappropriation.

The public judges a profession by the examples it meets. When the public sees men who are unlettered and untrained holding themselves out as "engineers," respect for the engineering profession is weakened or destroyed. When the public sees the word "engineer" on the shop window of a plumber, an electrician, a radio dealer, or an automobile mechanic, a wrong picture of the engineering profession is implanted.

For years, the engineering profession talked about this problem—the abuse and misuse of the term "engineer"—but nothing was done about it. Finally with the aid of registration laws, means for successfully protecting our designation became available.

At first, public officials were slow to co-operate. They declared that we could not "copyright the dictionary." We pointed to the precedents of the other legally established professions which had successfully "copyrighted large chunks of the dictionary." Any unlicensed man hanging out his shingle as a "lawyer," a "physician," a "dentist," or an "architect" will be promptly arrested and subjected to the penalties of the law. These respective professions will see to it, and the agencies of the law will back them. (Recently, in New York, the legal profession had an insurance agent arrested because he allowed a customer to call him "counselor" without correcting her.)

Clauses protecting the designation "engineer" have now been written into most of the state registration laws, and have been made enforceable. In New York State it is now unlawful for any unlicensed person "to use the title engineer or any other title, sign, card, or device in such manner as to tend to convey the impression that such a person is a professional engineer." The Tennessee law forbids unregistered persons to "use the appellation architect or engineer, or any appellation which is a compounding, modifying, or qualifying by an adjective of the words architect or engineer, or both."

These and similar provisions of the registration laws in the various states have been tried and tested for scope of effectiveness. In the past few years, hundreds of violations have been successfully corrected, largely through voluntary co-operation.

Enforcement of Registration Laws

When the engineers' registration movement was young, many disregarded it or were ignorant of it because enforcement and publicity were lacking. Teeth have now been put into these registration laws, and enforcement procedure is being progressively strengthened. The machinery of enforcement has been put into effect, and men have been arrested, tried, and fined for practicing engineering without a license.

In one court, a man was convicted of manslaughter for the collapse of a structure which he had designed without a license to practice engineering. In another case, an unlicensed man was sentenced to the workhouse for using the designation "civil engineer" on his letterhead.

In 2 years in California, 23 violations of the engineers' registration law were prosecuted in the local courts, resulting in 21 convictions for unlicensed practice. The maximum penalty assessed was a fine of $100 or 50 days in the county jail.

In one year, 105 unlawful listings as "engineers" were eliminated from the New York City telephone directory, and 217 other violations were handled by the New York State enforcement authorities and corrected without resort to the courts.

The civil courts have established a significant precedent in repeatedly dismissing actions for the collection of engineering fees when such actions were brought by men who were not registered as engineers. The courts have ruled that a contract for engineering services is invalid if the party undertaking to furnish such services is not registered.

The courts have repeatedly disqualified men offering engineering testimony when such "experts" were found to be unregistered.

The supreme court of Tennessee ordered a concern to abandon its trade name "The Standard Engineering Company" because the members of the firm were not registered engineers.

The courts have ruled that even college graduates with professional degrees may not use such designations as "civil engineer" or "electrical engineer" until they are admitted to professional registration.

In New York State, 7 professional engineers nominated by the State Society of Professional Engineers have been sworn in as deputy investigators and added to the official enforcement staff to assist in investigating and correcting reported violations in the various parts of the state.

In Oregon, following approval by the attorney-general, funds from registration fees are used for a statewide campaign of newspaper advertisements informing and warning investors, employers, mine operators, engineers, industries, and utilities, concerning the requirements and purposes of the engineers' registration law.

Public officials are progressively taking a keener interest in the enforcement of engineers' registration laws. Construction plans signed by unlicensed men are rejected by federal and local officials. Men not registered as engineers are debarred from holding office as county engineers or city engineers. Civil service commissions are co-operating by requiring a license as a prerequisite for appointment to engineering positions. In every way registration laws are becoming more real and more effective in their operation.

Educational Qualifications

In recent years, another step of progress has been recorded in engineers' registration laws. We have brought the legislators and the public to recognize the fact that engineering is not an empirical calling, but a learned scientific profession. In recognition of that fact we have written into the laws educational requirements for the licensing of engineers. The laws now generally require qualifications of moral character, evidence of completion of academic and professional education, and in addition a number of years of practical experience in engineering work of a character satisfactory to the state board of examiners. Both college graduates and nongraduates have to pass written examinations. The gates are not yet barred to the man who has not had the advantages of a college education, and he is given an opportunity to show by examination that he has the equivalent technical training. Where a minimum of 4 years of practical experience is required of graduates of approved colleges of engineering, a minimum of 8 years (soon to be changed to 12 years) is required of the nongraduate before he is admitted to the licensing examinations, and in his case the examinations are necessarily more comprehensive.

Through high standards for registration, we can impress upon the public the fact that engineering is a learned profession.

Registration and Professional Unity

Another important principle that has been recorded through the agency of our registration laws is that of the solidarity of our profession. We have recorded the principle that engineering is *one* profession, although specialties may be many. We do not license the specialist; we license the engineer. We do not place any limitation upon the branch or specialty in which he may engage; instead we expect the board of examiners to make sure, before granting a license, that the man can be trusted not to engage in any specialized work in which he may not be qualified.

The same principle has long been established in the medical profession. That profession has firmly and consistently resisted every suggestion of legal division or superqualifications into specialties. Self-limitation of field of practice has been kept a matter of professional honor, and legal limitation has been rejected.

Others may wish to emphasize the diversification of engineering into specialties. It is for us to proclaim the fundamental unity of our profession. Whether a man writes "E.E.," "C.E.," "M.E.," "E.M." or "Chem.E." after his name, he has the same common basic educational training, the same governing professional qualifications, the same method of analytical approach to technical problems, the same ideals of professional practice, and the same interest in the profession's problems of public recognition, protective legislation, and relations with other professions.

Law and medicine have as many specialties as engineering, but lawyers and doctors would never approve of the legal subdivision of their professions.

Some of the states license men in specialties or branches of engineering. It is the prevailing opinion that such procedure is a mistake. Registration can and should be used to proclaim the essential oneness of our profession.

Protection Against Restriction of Practice

Another effective application of our licensing laws has been in the protection of engineers against discrimination and restriction of fields of practice. Our profession has taken the position that we do not seek to interfere with the rights of practice of any other profession, but at the same time we have firmly recorded the principle that we will not allow any other profession to restrict the rights of practice of the engineer. We have had our battles on that issue and the victory has been won.

In different states, legislation sponsored by architects would have eliminated or subordinated the engineer in the structural field; physicians endeavored to monopolize the sanitary field; accountants sought to exclude others from the making of financial reports; lawyers sponsored legislation which would have deprived engineers of the right to prepare contract documents and to engage in arbitration proceedings; and real estate brokers endeavored to monopolize the right to make appraisals. Such legislation has been consistently and successfully opposed by our profession. Suggestions to meet the situations by subdividing into specialties have also been consistently resisted.

Without our registration laws on the statute books, recording the rightful scope of practice of the professional engineer, our cause would have been lost. We would have been subordinated to other professions, our established field of practice diminished, and our profession dismembered.

The Model Registration Law

With the participation of several leading national and local engineering societies, a "model registration law" has been developed to serve as a guide for the drafting of new laws and the improvement of existing laws.

The definition of professional engineering, first written into the New York State law and then incorporated in the "model law," is as follows:

> "The practice of professional engineering within the meaning and intent of this Act includes any professional service, such as consultation, investigation, evaluation, planning, design, or responsible supervision of construction or operation, in connection with any public or private utilities, structures, buildings, machines, equipment, processes, works, or projects, wherein the public welfare, or the safeguarding of life, health or property is concerned or involved, when such professional service requires the application of engineering principles and data."

The minimum qualifications for registration as a professional engineer, also following the standard established in the New York State law, are:

> "*a.* Graduation from an approved course in engineering of 4 years or more in a school or college approved by the board as of satisfactory standing; and a specific record of an additional 4 years or more of active practice in engineering work of a character satis-

factory to the board, and indicating that the applicant is competent to be placed in responsible charge of such work; or

"b. Successfully passing a written, or written and oral, examination designed to show knowledge and skill approximating that attained through graduation from an approved 4 year engineering course; and a specific record of 8 years or more of active practice in engineering work of a character satisfactory to the board and indicating that the applicant is competent to be placed in responsible charge of such work."

Registration laws introduced for enactment since 1932 have generally followed the "model law" closely as a standard. It has been a most helpful contribution toward uniformity.

The "model law" has had, in its preparation, the benefit of all past experience and the best constructive thought of the profession. It is offered as the best draft of a registration law thus far developed by the profession, with all legal requirements carefully observed. The "grandfather clause" is retained, protecting any established individual rights of practice, in order to remove the only objection that has ever been brought against such legislation on constitutional grounds; and a "saving clause" is included to preserve the validity of the rest of the law in the remote eventuality that any section in it might be declared invalid. The constitutionality of such legislation is now well established.

Registration Fees

The registration fee is not an occupational tax. It is not intended as a source of revenue to the state. The "model law" provides that all fees collected should be used for the administration and enforcement of the law. Fees vary in the different states from \$5 to \$25 for the original registration certificate and from \$1 to \$5 for annual renewal. Engineers should not begrudge this comparatively slight contribution to protect their professional investment.

The slight expense imposed on engineers as a registration fee is trifling in comparison with the benefits derived. Anything that raises the standards of qualification and recognition of the profession benefits all engineers in it. The man who has invested thousands of dollars in education and many years of his life in training for the profession, should not hesitate to spend the small amount of the registration fee in order to protect and enhance the value of this investment. Many an aspirant to practice law or medicine would gladly pay many times as much to secure his admission to practice; so would many who have been rejected for engineering registration.

It is for the profession to estimate how small the registration fee can be made with assurance of adequacy to cover the expenses of administration of the law. In Colorado, where a surplus accumulated, the profession secured the passage of a bill to expend the fund for the establishment of a large engineering reference library. In New York, the state has retained a surplus of nearly \$300,000 out of the fees collected, principally in the early years of large volume of applications; such profit was not intended. The aim is to adjust fees to the cost of administration, and to use any surplus for improving the enforcement organization. In time, legislators will be educated to appreciate that at least half of the total cost of registration and enforcement should be contributed by the state, since the law is primarily for the protection of the public.

Reciprocal Registration

Although many of the state laws contain provisions making it permissive to enter into agreements for reciprocal registration such procedure as between any 2 states is unworkable unless the 2 states have identical qualification requirements and standards. As a rule, no state is willing to delegate its qualifying authority to another state. Consequently, formal application for registration has to be made in each state in which the candidate desires to practice. Possession of previous registration in another state is given due weight in considering the application, and may be grounds for waiving examinations and examination fee.

Since engineering practice is frequently interstate in character and many engineers have a nationwide practice, it is important to facilitate interstate registration. For this purpose, the National Council of State Boards of Engineering Examiners (comprising 26 state registration boards) had established a National Bureau of Engineering Registration to serve as a central examining and certifying agency. The national bureau maintains the qualification requirements specified in the "model law," which are equal to or higher than the requirements of any state, and its certificate is accepted by the individual state boards as prima facie evidence of qualification without further examination. The national bureau application fee is \$10, and many of the states (as suggested by the "model law") reduce their registration fee from \$25 to \$10 when the national bureau certificate is presented.

The procedure of utilizing a National Bureau of Registration follows successful precedents established by other professions, including medicine and architecture. It is a necessary expedient since it is impossible under our constitution to make registration a federal activity.

In addition, most of the state registration laws permit unlicensed practice for 60 days in any calendar year by a nonresident who is registered in his own state, and for a further period if application is filed for registration and until such application is granted or denied.

It is one of the objectives of the National Society of Professional Engineers to extend and improve registration legislation until every state in the Union has a model uniform registration law, with complete reciprocity for interstate practice.

Co-operation of Corporations

The engineer who is registered is more valuable to his employer, and many organizations require that their employees be registered. It is an asset to a firm to be able to announce that all of its employees are registered engineers.

Large railroads, exempt under the registration laws, have directed all of their assistant engineers to secure registration, in anticipation of legal questions

of responsibility that might arise. Other corporations have voluntarily instructed their men to secure registration, withdrawing the title of engineer from those that failed to do so. Some corporations, anxious to have all of their engineer employees registered, are paying the registration fees for their men. Some firms require the engineers in their organizations to be registered in order to be qualified to give expert testimony. Employees making the design or inspection of structures should be registered, otherwise criminal liability is incurred in a failure.

With better understanding, the general attitude of corporations toward engineers' registration has been progressively changed from resistance to cooperation.

Registration and Politics

It is true that registration means the entrance of the profession into legislative activities, but it is certainly high time that the profession make its influence felt in legislative councils.

Once a proper registration law is enacted, no political influence need be feared to pervert the administration of the law. The members of the registration boards are engineers of high standing, nominated by the profession in each state; and, since their service is one of devotion to the profession, self-sacrificing and nonlucrative, there is no inducement to make the appointments a political consideration. Examinations, registration, and revocations are handled by the board of examiners, and cases of unlawful practice are decided in the courts.

The administration of the registration law is kept on as high a plane as the standards of the profession.

Registration and Ethics

Registration is the only means by which our profession can enforce its codes of ethics and fair practice. Without registration laws, codes of professional conduct and fair practice are merely documents that may or may not be respected by the individual. But with the backing and sanction of the law we have it in our power in the future to make these standards of ethics enforceable and to stop the practice of those who, by their malpractice, are injuring beyond repair the good name of our profession. The registration laws generally provide for revocation of license for evidence of incompetence or misconduct in professional practice.

In Ohio, the engineers' code of ethics is printed on the application form and is required to be signed by the candidate before his application for registration is considered. By legal ruling, such advance subscription to the code will facilitate disciplinary action for any subsequent violation. In addition, the county organizations of professional engineers have been asked to formulate and adopt local codes of practice and fees for adoption and disciplinary enforcement by the state boards of examiners.

The legal profession has recorded in the statutes strict penalties for various unprofessional acts, such as threatening lawsuits in collection letters or soliciting professional engagements. The penalty for dishonorable or unethical conduct is fine, imprisonment or disbarment.

Other professions, in their registration laws, have empowered their state boards to define unprofessional conduct and the courts have supported such authority.

In Canada, engineers' registration is strongly established and is administered by the Provincial Associations of Professional Engineers; registration and membership are synonymous. In Quebec and other Canadian provinces, the code of ethics and the code of fees are written into the law by reference, and any violation of these codes is cause for revocation of license to practice.

In the United States, the machinery of disciplinary action under the engineers' registration laws has already been put into effect, and licenses have been revoked on proof of incompetence, misrepresentation, and unprofessional conduct.

Extension of Registration

No state can afford to be without an engineers' registration law. No state can afford to become the dumping ground for the incompetent and the unscrupulous who are barred from the profession in other states. The individual engineer, if his own state has no registration law, is handicapped in securing reciprocal registration in other states; registered or unregistered engineers from all other states can come into his territory to compete with him, but he cannot practice in their states. Above all, the profession in any state cannot afford to be left out of the progressive advancement and accomplishments of the profession in other states. Registration legislation is the key to such accomplishment for the advancement of the profession.

The enactment of a registration law in any state is generally marked by a new awakening of professional consciousness and unity among the engineers of that state.

Some years ago, the American Society of Mechanical Engineers appointed a "committee on the economic status of the engineer." That committee, in its final report, concluded that the prime essential for advancing the status of our profession is the establishment of a clearly recognizable line of demarcation to distinguish the engineer from the nonengineer. In my opinion, registration is the only means of establishing this desired demarcation.

Registration has been used by other professions as a powerful instrumentality for raising educational qualifications, ethical standards, professional status, and public recognition. It will do the same for the engineering profession. It is the only enforceable means of protecting the practice and the designation of the profession against misappropriation and misuse by the unqualified and the unprofessional. Registration is the most effective instrumentality for impressing upon lawmakers, officials, and the public that:

1. Engineering *is* a profession.
2. Engineering is a *learned* profession.
3. Engineering is *one* profession.

Discussions

Of A.I.E.E. Papers—as Recommended for Publication by Technical Committees

On this and the following 8 pages appear 2 additional authors' closures of papers presented at the 1935 A.I.E.E. winter convention, New York, N. Y., January 22–25, and the first discussions submitted of papers presented at the general technical and the insulation and protection sessions of the South West District meeting, Oklahoma City, Okla., April 24–26, 1935. Authors' closures, where they have been submitted, will be found at the end of the discussion on their respective papers.

Members anywhere are encouraged to submit written discussion of any paper published in Electrical Engineering, which discussion will be reviewed by the proper technical committee and considered for possible publication in a subsequent issue. Discussions of papers scheduled for presentation at an A.I.E.E. meeting or convention will be closed 2 weeks after presentation. Discussions should be (1) concise; (2) restricted to the subject of the paper or papers under consideration; and (3) typewritten and submitted in triplicate to C. S. Rich, secretary, technical program committee, A.I.E.E. headquarters, 33 West 39th Street, New York, N. Y.

Resistance and Reactance of 3 Conductor Cables

Authors' closing discussion of a paper published in the December 1934 issue, pages 1581–9, and presented for oral discussion at the cables session of the winter convention New York, N. Y., January 24, 1935. Other discussion of this paper was published in the March 1935 issue, pages 324–6, and in the April 1935 issue, pages 436–7.

E. H. Salter, G. B. Shanklin, and **R. J. Wiseman:** In reference to the comments by R. W. Atkinson in regard to the difference found when the phase rotation of current was reversed, analysis of these data did not give a logical reason why a difference should be found. We could not explain it on the basis of accuracy of test methods because the difference is in the same order of magnitude as was found for other factors which we knew did influence a-c losses. It was decided to include the data in the paper with the hope that someone could offer a reason for that which we found.

Atkinson's comments on the disruptive effect of heavy currents are quite interesting. We are glad to see that his tests confirm that which is reported in the paper, namely, that for the expected values of short circuit currents, it is not necessary to provide for special binders to hold the conductors in place. As we must use a binder of some form in manufacture and a lead sheath, we do provide a reinforcing for those instances where extra heavy currents are likely to occur.

It may be that the effects of short-circuit currents on belted cables weaken them electrically and, therefore, eventually result in failure. However, to get a short circuit a failure must first take place, and in view of the speed with which circuits are opened, it seems a bit difficult to picture a permanent effect in the cable which eventually causes further failures. It would seem as though effects of oil migration are more readily responsible for the poor showing of belted cables as compared to shielded cables.

Louis Meyerhoff's comments are greatly appreciated. It would have been helpful to the committee handling the preparation of the paper if his ideas of proximity effect had been given them for consideration as possible explanations of the experimental data. As far as it was possible theoretical reasons for the total increase in conductor resistance were given and theoretical calculations checked remarkably well, except in thoses cases where the strands were all laid in the same direction. By eliminating the calculated proximity effect, the theoretical increase in resistance very closely equalled the actual; in other words, proximity effect was zero. Meyerhoff's reason is logical, but it must be remembered that the oxidized surface of the strands also aids normal stranding in reduction of proximity effect when the strands are highly crushed.

Referring to W. H. Cole's statement that the extra losses in his 3 conductor cable represented a deficiency of the order of from 5 to 8 per cent, or approximately \$25,000, this is presumably based on the maximum carrying capacity of the cable line. Whether it is an actual deficiency or not, of course, depends upon whether the present or future peak loads required of this line become equal to the maximum allowable carrying capacity. This in turn depends upon how much reserve capacity this cable line was laid out for in the beginning.

The fact that magnetic binder cable has about 20 per cent higher reactance than nonmagnetic cable is of no particular importance so far as voltage regulation of the system is concerned and becomes only of importance when an attempt is made to parallel magnetic and nonmagnetic cables. Everything else being equal, a nonmagnetic cable should be preferred, but there would still be a demand for magnetic binder cable for purposes of paralleling in those systems where the practice of using magnetic binder cable is already being followed.

The last part of Cole's discussion seems to be based on the misconception that minimum proximity effect is realized with solid bar conductors. A comparison of the data in our paper will show that solid bar conductors cause maximum and not minimum proximity effect.

Compact rolling of the strands results in minimum proximity effect, although in physical appearance this type of stranding approaches nearest to solid bar. The reason for these 2 cases representing extremes of proximity effect is fully explained in the paper. Rolling of the strands gives much larger contact area between strands and a more uniform distribution of cross currents. These currents in turn are reduced in total value by the contact resistance as represented by the natural oxide film on the surface of each strand.

Constant-Current D-C Transmission

Authors' closing discussion of a paper published in the January 1935 issue, pages 102–8, and presented for oral discussion at the general overhead line problems session of the winter convention, New York, N. Y., January 23, 1935. Other discussion of this paper was published in the March 1935 issue, pages 327–9, and in the April 1935 issue, pages 447–9.

C. H. Willis, B. D. Bedford, and **F. R. Elder:** In answer to the questions regarding the operation of the monocyclic network, the following simple vector analysis of its operations is submitted.

The balanced monocyclic network, composed of pure inductive and capacitive ele-

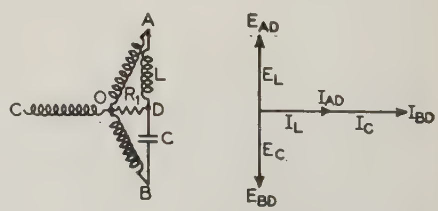


Fig. 1. Monocyclic vector diagram, special resistive load

ments, theoretically produces an absolute constant voltage-constant current transformation. In practice the losses are small, and results closely approaching the theoretical are obtained. When an inductance and capacitance of equal impedance are connected in series across a constant voltage source, a constant current must flow out the common connection of the 2 impedances.

For simplicity consider 2 special loads of

such a value that the capacitor and reactor currents add in phase to produce the load current. In figure 1 of this discussion the constant voltage AB is impressed on X_L and X_C in series. With the resistance load R_1 connected to the neutral of the a-c system, the voltages and currents are represented by the vector diagram.

The inductive current lags the voltage on X_L by 90 degrees, while the capacitive current leads the capacitor voltage by 90 degrees. The current in the resistance R_1 is the sum of these 2 currents.

In figure 2 the load consists of the series resistance and inductance R_1 and L_1.

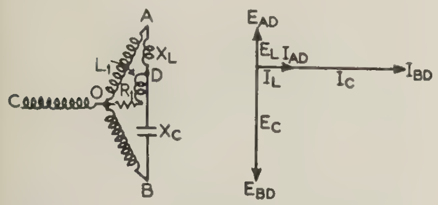


Fig. 2. Monocyclic vector diagram, special resistive and inductive load

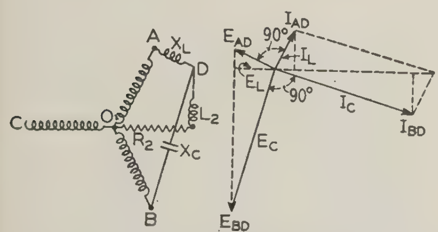


Fig. 3. Monocyclic vector diagram, resistive and inductive load

The voltage on X_L is decreased and its current is decreased in proportion, but a corresponding increase of voltage on X_C increases its current, producing a constant current output.

In figure 3 the series loads R_2 and L_2 produce voltages on X_L and X_C, shown by the vectors E_{AD} and E_{BD}. The current in X_L lags the voltage E_{AD} by 90 degrees, while the current in X_C leads the voltage E_{BD} by 90 degrees. Dividing the voltage and currents into components in phase and 90 degrees out of phase with the voltage E_{AB}, it is seen that the resulting load current is proportional only to the voltage E_{AB}, while the other components of current are equal and opposite and contribute nothing to the resulting current. With other loads of different magnitude and power factor, the point D in the potential diagram varies in or out, up or down, depending on the impedance of the load, but the current in the load remains constant both in magnitude and phase position.

With the apparatus shown in figure 5 of this discussion it has been demonstrated:

1. That either rectifiers or inverters can be put on the line in any order.

2. That load may be changed from ful load to no load and back.

3. That the rectifier and inverter currents remain practically constant with a short circuit on the d-c line and that the current through the fault is very small, normal operation being resumed upon removal of the fault.

4. That no harmful voltage occurs with an open circuit of the d-c line, and on closing the circuit operation resumes.

5. That any tube in either rectifier or inverter can be short circuited or open circuited, the direct current remaining substantially constant, some change in load (voltage) occurring, but that normal operation will be resumed with removal of the fault.

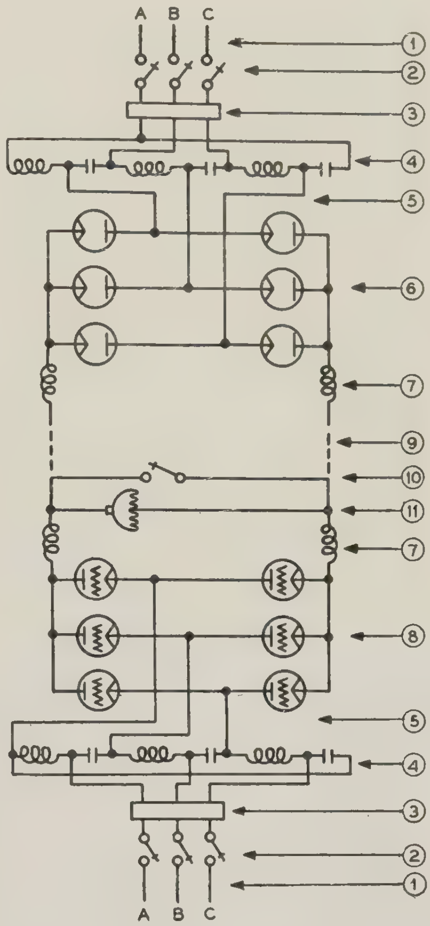


Fig. 4. Diagram of a constant-current d-c transmission system

1. 3-phase a-c constant voltage power system
2. Disconnect switch
3. Oil circuit breaker
4. Monocyclic network
5. 3-phase a-c constant current
6. 3-phase full wave rectifier
7. D-c reactor
8. 3-phase full wave inverter
9. Constant-current d-c line
10. Short circuiting switch
11. Disk insulator for flashover test

Fig. 5. Apparatus for demonstration of constant-current d-c transmission

Instantaneous Overcurrent Relays for Distance Relaying

Discussion and author's closure of a paper by C. H. Frier published in the April 1935 issue, pages 404–7, and presented for oral discussion at the general technical session of the South West District meeting, Oklahoma City, Okla., April 24, 1935.

L. C. Grigsby (Public Service Company of Oklahoma, Tulsa): The paper gives a good example of the application of instantaneous relays to a complicated transmission system. It emphasizes one very important point; that is, the importance of accurately determining the short-circuit currents on the system. This is absolutely essential for correct operation. The curves in figures 2 and 3 give a very good and systematic method for determining the relay setting and co-ordination. The application to lower voltage feeders in connection with fuses, as illustrated in figure 4, is interesting, in that it offers a satisfactory solution to a problem which has frequently been encountered.

There is one minor point on which I differ slightly with the author and that is the use of the internal relay, or "instantaneous trip attachment," versus the external relay. It is true that the cost of the external relay is somewhat greater than the internal attachment. However, for the more important lines or trunk feeders, we believe that the advantages, which include better provision for inspection, testing, calibrating, and ordinary maintenance, warrant the slight additional cost of the external relay over the internal relay.

On the system of the Public Service Company of Oklahoma the instantaneous overcurrent relays have been used for about 3 years. Our experience with them has been quite gratifying. In checking over the operating results, it was found that the percentage of relay operations checks very closely with those given in the paper. We have one case in which the instantaneous relays are used to relay the entire length of the line for any value of fault current. This section of line terminates in a stepdown transformer bank which introduces sufficient impedance to permit backing up of the relays on line sections fed from the low voltage side of the transformer bank. Out of a total of 11 relay operations since the installation of the instantaneous relays on this section of line, we have had but one instance when they failed to clear the fault. This resulted from the failure of the relays on the

low side of the transformer bank to operate.

The paper points out the necessity for considering the different combinations of generating capacity as influencing the setting of the relays and length of line section effectively protected. At one generating station of 30,000 kw capacity, consisting of 2 15,000 kw units, we have installed 2 sets of the instantaneous overcurrent relays having their operating coils in series. One set of these relays is given a high current setting corresponding to fault currents, with 2 machines operating on the system; the other set of relays is given a lower setting for fault currents, with one machine operating. A switch is provided to shunt out the operating coil of the lower setting relay when both generators are operating.

We have found that the instantaneous relays have materially improved our system stability by preventing the generating stations on loop circuits from pulling apart at the time of faults on the system. Through the rapid isolation of faults, the relays have prevented long duration of low voltage dips, and, consequently, have greatly improved service to the customer.

E. E. George (Tennessee Electric Power Co., Chattanooga): This paper brings out clearly the fundamentals of a scheme of relay protection that is being used rather extensively by certain companies. One company in the southeastern section has made extensive use of this type of protection with very good results. Its successful application seems to depend upon the amount of short-circuit kilovoltamperes being relatively constant under all generating conditions or in those cases where the variation is moderate, upon knowing accurately what the currents are under various conditions.

Judging by our own experience, we are convinced that all types of distance relays will operate successfully over long periods of time with very little maintenance; in fact, during the last 3 years our reactance type distance relays have probably had less attention than any other relay on the system. Improved types are now being brought out and, judging by their mechanical design, they should give still better service. Another advantage of the distance relay is that its starting unit makes an ideal fault detector or initiating unit for pilot wire circuits. We believe that this is a considerable advantage because much progress is being made in pilot wire reliability, pilot wire terminal equipment, and in the application of lower cost circuits to pilot wire protection.

C. H. Frier: L. C. Grigsby states that his company uses the external instantaneous overcurrent relay rather than an "instantaneous trip attachment" mounted inside the induction type overcurrent relays on the more important lines and trunk feeders because they believe the slight additional cost is warranted.

We considered both types of relays and decided in favor of the internally mounted instantaneous relay, first because the external relay cost 3 times more, and second because in the majority of cases we had no switchboard space available. The internally mounted relay setting, once adjusted, remains fixed and cannot lose its adjustment as we have developed a method to lock the adjustment in place. Relay field men find little difficulty in adjusting and maintaining these relays. They are reliable and the only maintenance required is the inspection and cleaning of the relay contacts. We therefore had no good reason for increasing our relay investment by buying the more expensive external instantaneous overcurrent relay.

E. E. George in his discussion points out the trend from the old overcurrent to the newer distance type relay. There is no doubt that the experience of many utilities will bear out this statement. We also feel that the distance relay is undoubtedly the answer to many vexing relay problems and we too may be forced to apply them to some points on our system, but for the present, since our generating conditions for 24 hour periods are practically constant, we can see no immediate necessity for retiring our relatively large investment in overcurrent relays. Furthermore, with the system characteristics as they are at present, we do not believe that the use of distance relays would give any material improvement to service. Also, the instantaneous overcurrent relay which we are using is obviously much easier and cheaper to maintain. To replace these devices with distance relays would represent a large investment which we believe would not be commensurate with the benefits to be obtained. The science of relaying in the past years has lagged far behind the growth of power systems until most systems were quite saturated with the older types of relays long before the more desirable relays were available, thus the question has become one of economy.

A Power Company Communication System

Discussion and authors' closure of a paper by E. E. George and O. J. Huie published in the March 1935 issue, pages 262–5, and presented for oral discussion at the general technical session of the South West District meeting, Oklahoma City, Okla., April 24, 1935.

O. S. Hockaday (Texas Electric Service Co., Fort Worth): In the development of a communication system for the use of power companies there is a growing tendency toward the co-ordination of service lease from the telephone companies and the service afforded by lines and apparatus owned exclusively by the power companies. Many power companies are finding it to their advantage in expanding their communication facilities to lease service from the telephone companies.

The extent to which such co-ordination can be carried out, however, depends very largely on the willingness and ability of the personnel of both the power and the telephone company involved toward cooperation. In most cases the power company already has some facilities which it must continue to utilize to the fullest. Any service supplied by the telephone company should fit into the existing system so that to be as flexible as possible. This generally involves interconnection between leased and privately owned lines.

If the power company is willing to install reasonable protective equipment, and the telephone people will assume a liberal attitude in the matter, there is no reason why such interconnection could not be established without any hazards to either.

The engineering aspects of the problems involved have been pretty well worked out, but a broad open-minded commercial policy must be observed if the power companies are to be encouraged in making wide use of leased service.

J. D. Browder (Oklahoma Gas and Electric Co., Oklahoma City): There is a point brought out in the paper which is unusual among operating companies in this section of the country, and in order to present that point I shall briefly trace the development of the Oklahoma Gas and Electric Company's communication facilities.

In many respects the growth and development of the system compare with those of the Tennessee Electric Power Company. When our first transmission lines were built in 1919 to connect the towns of Drumright, Sapulpa, Beggs, and Muskogee, a private telephone circuit was also installed on the same poles with the transmission lines. Other lines were later built to connect Oklahoma City, El Reno, and Enid, followed by the building of one of our first large central generating stations, Horseshoe Lake, located 22 miles east of Oklahoma City at Harrah. Two transmission lines were constructed between Harrah and Oklahoma City, on one of which was installed a private telephone circuit. With the exception of this circuit and the first one previously mentioned, our telephone communication was handled over commercial circuits at regular toll rates. But as our original properties were extended and interconnected to form a unified power system with a central dispatching office at Oklahoma City, additional communication facilities were required.

In 1924 carrier current equipment was installed at Oklahoma City, Enid, and Sapulpa, followed by similar installations at Etowah and Ponca City. The equipment at these 5 stations could be used only for dispatching purposes and was of practically no value for other company business owing to the lack of sufficient terminal facilities. Considerable capital investment would have been necessary to provide these facilities as well as to install additional station equipment to meet increasing requirements resulting from a rapidly expanding power system. With the expansion of the system to Shawnee, Ada, Ardmore, and other points in southern Oklahoma, the volume of business handled from the general office at Oklahoma City made it necessary to use toll service in increasingly large amounts. This situation, therefore, resulted in the need for more and better telephone service at less cost than could be obtained over usual commercial circuits. Consequently, in 1930 our company contracted with the telephone company for private leased wire service, and the carrier equipment was then dismantled.

This private service consists of approximately 550 miles of telephone circuits con-

necting the general office with the various generating stations and division headquarters at Enid, Sapulpa, Muskogee, Shawnee, and Ardmore, as well as numerous intermediate towns, switching stations, and substations. Private branch exchange switchboards are installed in the general office and at each division office, with operators on duty during regular business hours. The 4 principal circuits comprising the leased service radiate from the Oklahoma City board, where 2 operators are on duty during business hours handling traffic for all departments of the company. Dispatching calls are given priority over all other business on these circuits. Between 5:00 p.m. and 11:00 p.m. only one operator is required, and upon retiring from the board at 11:00 p.m. the leased wire circuits are switched directly into the dispatcher's office, where they terminate in a key-type switchboard designed especially for our purposes. Thus until 7:00 a.m. the dispatchers have direct control and supervision of the long distance circuits, at which time they are again switched back to the main private branch exchange board in the general office building.

Our dispatcher's switchboard is built in duplicate, yet it consists of one integral unit mounted flush in the middle of a large 2-position flat top desk so as to be accessible to each of 2 dispatchers who are constantly on duty. Each desk position is provided with 2 dispatcher's telephone circuits, a magneto and a common battery, which terminate in separate hand-type desk sets. The switchboard itself consists of a magneto section and a common battery section with all circuits being equipped with a battery operated lamp and buzzer alarm calling signals. Four 2-way dial trunks from the general office private branch exchange and one unlisted 2-way dial trunk from the central office terminate in the common battery section. In the magneto section we have the leased wire circuits as well as a 2-way rural trunk to the central office. The rural trunk provides quick communication with certain outlying substations regularly reached by rural telephone lines. It also enables the dispatcher to set up a connection between any leased wire circuit and any local dial telephone, as the switchboard itself has no direct means of interconnecting the 2 sections. This latter function, however, seldom becomes necessary on account of the unusual hours that the dispatcher has control of the leased wires.

In addition to the leased equipment just described, our dispatching communication facilities are supplemented by 6 company-owned magneto lines which are classified as exposed to power lines. These circuits terminate in a separate key-type switchboard built by our company and conveniently mounted on the desk within reach of each dispatcher. It, also, has 2 telephone circuits which terminate in separate desk stands so that either dispatcher may use the equipment separately or both simultaneously. Incoming signals are of the buzzer drop type; and a company-owned motor driven ringer is regularly used for calling, although hand driven ringers are provided for emergencies. By proper use of the keys, 2 or more lines may be connected by the dispatcher, in which case he serves as an operator for establishing communication between parties on different company-owned lines. Thus, we have 2 situations, which rarely occur and require very little attention when they do occur, where our dispatchers act as telephone operators.

Now, one of the outstanding features of the paper under discussion is the fact that the Tennessee Electric Power Company's dispatchers act as telephone operators in handling all calls no matter whether they are of an operating, commercial, or administrative nature. Not knowing anything about the conditions or volume of traffic handled, it appears that the dispatchers would be considerably handicapped in discharging their regular duties because of the time and attention required in serving as telephone operators. We would appreciate further enlightenment on this matter.

E. E. George and **O. J. Huie:** O. S. Hockaday mentioned one factor of extreme importance in stating that successful co-ordination of communication facilities depends very largely on the willingness and the ability of the personnel of both the power company and the telephone company. His statement that the commercial obstacles to complete co-ordination require more attention than the engineering problem is to be heartily endorsed.

J. D. Browder's description of the Oklahoma Gas and Electric Company communication system indicates that the facilities described are applicable in other locations and may be obtained when desired. Answering his question about all calls on the power company's long lines being handled by the load dispatcher, I would say that the best proof of the feasibility of this practice is its successful use for over 2 years. The only additional burden imposed on the dispatchers is during the time when there is no system trouble since administrative and commercial calls are not completed during the time when the lines are required for dispatching. This arrangement has also permitted a reduction in the number of private branch exchange operators but has not increased the number of dispatchers required.

The dispatcher's facilities for handling calls to and from the company lines are much better than those of the operator and calls can be handled much quicker than the operator could handle them. Another saving is that when commercial calls are handled by the operator, both the operator and dispatcher have to listen for code ringing if the turret and private branch exchange are connected in multiple, or if they are connected in series there is an extra switching operation which delays dispatching calls.

The arrangement we are using has had widespread approval over the entire system because of the increased speed of handling commercial and administrative calls. The extra work required of the dispatchers is offset to a large measure by the speed of handling trouble calls and by their ability to get control over the circuit instantly in case of trouble.

Furthermore, this arrangement permits the private branch exchange operators to give more time to exchange calls from the general public, thus giving customers better service, especially when these calls occur (as they usually do) during system trouble when the company's long lines are very busy on operating calls.

Having tried both schemes we much prefer the one we are now using, and if traffic should get heavy enough to require additional help, we would prefer to add an extra dispatcher, rather than to trunk the long line calls to the private branch exchange and add an extra operator.

Cable Sheath Corrosion —Causes and Mitigation

Discussion of a paper by J. B. Blomberg and Norvel Douglas published in the April 1935 issue, pages 382–83, and presented for oral discussion at the general technical session of the South West District meeting, Oklahoma City, Okla., April 25, 1935.

W. F. Rogers (nonmember; Gulf Pipe Line Company, Houston, Texas): The authors have prepared an interesting and valuable paper in regard to the determination and reduction of corrosion losses on lead cable sheath. Although the principal material of construction of the oil pipe line industry is steel and no lead is used, the corrosion problem is just as important, if not more so. It is interesting at this time to discuss some of the experiences encountered in studying soil corrosion of steel pipe and, especially, those experiences which parallel those of utilities using lead cable sheath.

The paper has listed the causes of lead cable sheath corrosion as any or all of the following factors:

a. Stray earth currents
b. Chemical corrosion
c. Electrochemical theory
    1. Galvanic potentials
    2. Differential areation
    3. Variation in electrolyte

The oil pipe line industry recognizes that corrosion may, and often does, result from stray electric currents. These cases are restricted to districts where oil pipe lines parallel or cross electric railway lines. Due to the nature of the business of oil pipe lines, it is not necessary or advisable that they pass through cities of the size requiring electric street cars. As a consequence, they seldom encounter this type of corrosion trouble to any great extent. There are, however, a few cases where pipe lines parallel electric interurban tracks for long distances. In one of the latter instances it has been only recently that a major pipe line company found it necessary to make an extensive investigation of the stray current which their 8 inch line was carrying and which was resulting in a rapid rate of corrosion attack, even though the pipe had been coated with an enamel and a wrapper when laid. The result of the survey lead to the recognition and acceptance of the fact that the line was acting as the negative feeder to the various substations along the right of way. Through proper bonding and the installation of low resistance metallic feeders, the pipe line was made negative to the rails throughout its length, and the current was led from the pipe line through a metallic connection to the negative bus

of the generator without loss of pipe metal. Such instances, in the midcontinent section at least, are relatively few and constitute but a minor portion of the corrosion troubles of oil pipe lines.

The oil pipe line industry does not recognize, at this time, instances of pure chemical corrosion, as differentiated from the electrochemical theory, such as is done in showing the formation of lead carbonate from lead, and such as is done in explaining the corrosion of copper in nitric acid. Thus, while the presence of acetic acid and carbon dioxide with lead causes a specific type of corrosion, these chemicals in steel pipe line corrosion are evaluated largely in regard to the increase in hydrogen ion concentration they cause in the soil solution and without regard as to the type of the acid.

Corrosion investigators in the pipe line industry consider that the electrochemical theory of corrosion can be used to account for any case of corrosion attack found which is recognized not to result from stray electric currents. These cases account for the major portion of the corrosion which occurs.

The authors have cited the St. Louis-Kansas City toll cable which was found to carry electric currents changing, over short intervals, from negative to positive potential to earth with resultant collection and loss of current. Electric currents of this same type are found on practically all pipe lines. They are differentiated from stray currents and for want of a better name, are called "long line currents." Their presence was first established by K. H. Logan, chief of the corrosion section, Bureau of Standards, and first presented to the pipe line industry in the paper "Pipe Line Currents," Logan, Rogers, and Putnam, at the tenth annual meeting of the American Petroleum Institute, Chicago, Ill., 1929. The conditions which give rise to these currents have not been isolated, but are laid to soil conditions developing large cathodic areas on the pipe. These currents have been found to flow for long distances, sometimes increasing in amount for several miles before beginning to leave the pipe. In other cases they reverse in direction every few feet. Apparently they are the same type as found on the St. Louis-Kansas City toll cable.

When studies were first made of these currents a possibility appeared that "hot spots" could be found by locating the points at which they left the pipe. It became advisable to test this theory and as a consequence, a survey was made of an 8 inch oil pipe line on the Texas gulf coast. ("Relation of Long Line Currents to Soil Corrosion," Gill and Rogers. *Physics*, v. 1, Sept. 1931, p. 194–204.) The line was approximately 8 miles in length and 8 years of age. The long line currents were measured over the entire length of the line by determining the potential drop over consecutive 100 foot sections of pipe. As the pipe weight was known, these potential drops were corrected to amounts of current flow. After this survey was completed, the line was taken up, cleaned, repaired, and put back into service. When the pipe was cleaned, the pit depths in it were measured. From these data curves were plotted to show the relation of the deepest pit in each 100 foot section to the gain or loss of current across that section. The results were that for any given pit depth there were practically as many cases where current was picked up across its section as where current was lost. As a result, it was concluded that this type of survey could not be used to determine corrosive soil areas with any greater precision than 50–50.

In contradiction to these findings, another major pipe line company, during the last year, has inspected some 2,000 miles of pipe by measuring the current flow over 100-foot sections taken from 1,500 feet to 1 mile apart. If current flow reversal is noted, the measurements are back tracked until the point of discharge is found. They report that 80 per cent of the cases of current losses were found to be in corrosive soil.

It would be most interesting if a second complete inspection of a pipe line or a complete inspection of a lead cable sheath could be made with respect to the changes in long line current throughout its length and the relation to the pitting found.

The use of cathodic protection by the authors to stop corrosion attack of the lead cable is of great interest. It is only during the past 3 years that this method of protection has been given any great consideration in the pipe line industry, and that has been largely for natural gas lines. Thayer installed cathodic protection on a small natural gas transmission line near Houston, Texas, and obtained results which led to further studies of the method and its adoption for many natural gas transmission lines. (Bureau of Standards, third conference on underground corrosion, 1932.) Although the St. Louis-Kansas City toll cable was protected in this manner although bare, all installations to date of cathodic protection which have come to our attention have been on coated pipe. It is the purpose of the electrical protection in these cases to prevent pitting and rust holes from appearing in the pipe at areas where the soil has stressed the coating from the pipe or where holidays were left during its application. Copper oxide rectifiers are usually used and the pipe made negative to the extent of 0.8 volt. This large potential difference has been somewhat decreased in later installations. Where only a small fraction of the pipe is bare, as is the case in a well coated line, the large potential difference of 0.8 volt does not result in the use of uneconomic quantities of current. It is also now being found that continuous application of the cathodic protection is not necessary, but that the current may be switched off at periodic intervals. Tests to determine the extent of this feature are now under way and will undoubtedly result in a lower current consumption than now thought necessary.

It would seem that corrosion problems for lead cable sheath and steel pipe have many features in common and the exchange of experiences of each cannot help but be of benefit to users of both materials.

L. C. Starbird (Southwestern Bell Telephone Co., Dallas, Texas): This paper deals with a subject with which I am very much concerned at this time. In practically every city in Texas we have had, during the last 2 years, conditions favorable for corrosion of cable sheaths.

In the cities in which street cars are operating, the general procedure and technique of mitigation are definite and have been successfully applied. The only requirements for this are co-operation between the various users of subsurface structures and a large amount of effort on the part of the employees actually applying the mitigation measures.

The problem of corrosion from local conditions is an entirely different matter. In my opinion there are 3 very definite questions in connection with this problem. First, given a small positive potential from the sheath to earth, is serious trouble likely to develop? Second, if trouble is likely to develop, what measures of mitigation will be effective? Third, what expense is justifiable in applying mitigation measures?

Beginning in 1932 there were a number of street railway systems abandoned. With each of these it was found that there was a small positive potential, ranging from 0.01 to 0.2 volt, together with a small current flow on the cable sheath. At first it was thought that this was the result of the deposit of metals or minerals on the sheath by the currents that had been picked up by the cables during the time that street railways were in operation, and that these deposits would be dissipated in a short time. Subsequent tests made 1 and 2 years after abandonment have shown, however, that there is no appreciable change in the cable potential.

Meanwhile we were called upon by one of the independent telephone companies to help them with a very serious electrolysis condition in their Greenville, Texas, exchange. The condition there was very similar to the others except that there had been no source of stray current for a number of years. On one particular cable run, about 3 blocks long, there had been an average of one cable failure per year for several years, and in one case, a cable failed in less than one year after it was placed in service. An examination of this cable showed that action was not confined to a small section, but was general through the cable. From this we can draw the conclusion that wherever this type of action is going to cause cable failures, all cables in the vicinity will be seriously damaged by the time any one cable fails.

A check was made of the conditions in several representative small cities in which street railways had never been operated. It was found that in a number of these the same small positive potentials existed, and presumably had existed for a number of years. However, no serious electrolysis failures have been experienced and in one case an examination by excavation of small sections of the sheath, revealed no appreciable action. We therefore have the condition that in some cases of this type, no serious trouble will develop if no measure of mitigation is applied, and in other cases very serious trouble will develop, and if we wait until a case of trouble does develop the entire plant will have been damaged in the meantime. I feel, therefore, that some supplementary methods, such as chemical analysis of the soil or placing short sections of cable in vacant ducts for observation, are required to determine if trouble is likely to develop. These methods are either expensive or take a considerable time to apply.

As an experimental measure in several

instances we have applied counter potentials, generally by the same method described in the paper. This, however, becomes an expensive mitigation measure when applied to a network of cable in the city where other subsurface structures are in use, and where frequent connections between the cable network and building frameworks, etc., are present. It is then necessary to remove the metallic connections between the cable and all other subsurface structures to conserve the amount of current required, and to apply the counter potential at very frequent intervals to prevent large differences of potential between the cable and other subsurface structures. The elimination of all metallic connections is a slow process and requires considerable time. The amount of power required for the application of counter potentials, while small for the individual point of application, becomes an appreciable item where there are a number. There should be some economical balance between the probable loss from corrosion in actual expense and in interruption of service and the expense of providing mitigation measures. I have not had enough experience to date to make an intelligent estimate of this economic balance.

The mitigation measures used at Greenville are rather interesting, particularly as to the effectiveness of a rather simple mitigation system. This network is small, consisting of about 20 manholes and approximately a mile of duct line extending about equally in the 4 directions from the central office.

This network was positive and remained so with potentials ranging from 0.01 to 0.15 volt to earth. The sheath current was also comparatively small, ranging from 0 to 0.2 ampere in the 4 branches. This soil is the rich heavy black land type and the water seeps into the manholes in sufficient quantities to keep the cables under water most of the year. The manholes and duct line are heavily dirted and this mixed with the soil water forms a sticky black muck. An analysis of this soil water and slush from the duct line showed calcium carbonate ($CaCO_3$), iron oxide (FeO), calcium sulphate ($CaSO_4$), aluminium oxide (Al_2O_3), lead carbonate ($PbCO_3$), magnesium carbonate ($MgCO_3$), and arsenic oxide (As_2O_3), relative concentration being in the order named. The pH value (hydrogen ion concentration) was not determined. During the investigation an attempt was made to overcome this condition by the use of counter potentials. The cable was so heavily grounded that a reasonable amount of current applied at one manhole would not effect the cable potential at the adjacent manhole. However, during the survey it was discovered that one particular guy wire was very negative to the cable and other subsurface structures. Investigation revealed that this guy wire was anchored to sections of iron buried about 6 feet deep. A temporary bond between this guy wire and the cable pulled the cable negative for about the distance of one manhole on either side of the point of bonding. As an experimental measure standard iron ground rods were driven in the sump in the bottom of a number of manholes and bonded to the cable. This was very successful and as a permanent measure, 10 feet sections of 70 pound rails were driven into the ground in the bottom of each manhole, and connected permanently to the cable. Current flow readings showed that current was flowing in all cases from the cable to these grounds and in some cases was as high as 0.1 ampere. This arrangement made the cable negative to earth at all manholes except 2 which were remote from the area where electrolysis trouble had been experienced.

The connections to this ground in any one manhole would appreciably reduce the cable to earth potential in the manholes on either side. However, there was some doubt as to whether the overlap of the influence of the grounds in adjacent manholes was sufficient to fully protect the cable midway between manholes. A test electrode was pushed through a vacant duct and readings taken at frequent intervals to ground and cables in the manhole. These readings indicated that the overlap was sufficient to fully protect the cable. Duct electrodes, when examined one year later, revealed very little corrosion. While this system of mitigation was successful at Greenville, it is not expected that it can be applied in many other cases.

Recommended Transformer Standards

Discussion of a paper by H. V. Putman and J. E. Clem published in the December 1934 issue, pages 1594–7, and presented for oral discussion at the insulation and protection session of the South West District meeting, Oklahoma City, Okla., April 24, 1935. This paper was also presented at the winter convention, New York, N. Y., January 22, 1935, and other discussion was published in the July 1935 issue, pages 770–1.

J. K. Hodnette (Westinghouse Elec. and Mfg. Co., Sharon, Pa.): There has been considerable discussion recently amongst engineers relative to a revision in the proposed standards for transformers to more closely co-ordinate the transformer insulation levels with protective devices. This applies particularly in the lower voltage or distribution classes of transformers where a reduction in the insulation levels would be made. It is believed that this has been an outcome of the transformer subcommittee's proposal to increase the 60 cycle dielectric tests on the lower voltage transformers and had as its objective a reduction in distribution transformer costs.

A better understanding of these transformers and the factors involved will show the soundness of the subcommittee's proposal.

For many years transformer manufacturers have been building insulation into distribution transformers far in excess of requirements for withstanding the present A.I.E.E. acceptance tests. This has been dictated by service conditions, lightning, switching surges, arcing grounds, etc. The proposed revision in the low frequency dielectric tests merely applies a voltage more nearly what the insulation is capable of withstanding, and no actual increase in insulation has been necessary.

In order to give a clearer picture of the factors with which we are concerned table I of this discussion was prepared giving the percentage of the iron opening occupied by different materials making up a 5-kva 2,400-volt and a 5-kva 6,900-volt distribution transformer. These transformers are of different constructions. The 2,400 volt unit is shell type with low-high-low coil arrangement and the 6,900 volt unit is core type with a low-high coil arrangement on each leg with a barrier between legs. It will be noted that the total high to low and iron insulation on the 2,400 volt transformer is 16 per cent of the total space. The low to iron insulation which is the minimum thickness that can be used due to mechanical requirements is 10 per cent. If the high voltage insulation is reduced to the minimum for mechanical requirements, the saving in space would be but 6 per cent.

Table I—Space Occupied by Copper and Insulation in the Iron Opening of 5 Kva Transformers

	Transformer	
	2,400 Volt Per Cent Space	6,900 Volt Per Cent Space
High voltage to low voltage barrier	10	8
High voltage to ground barrier	6	6
High voltage to high voltage barrier		12
Low voltage to ground barrier	10	6
High voltage part coil barrier	4	3
High voltage to low voltage ducts		16
High voltage layer insulation	22.5	24
Low voltage layer insulation	12.5	7
Copper	35	18

Similarly, the total high to low and iron barriers in the 6,900 volt transformer occupy 26 per cent of the space. By reducing the insulation to that of the 2,400 volt transformer a saving of about 11 per cent in space results. However, this insulation would not withstand the present A.I.E.E. acceptance tests and would be unsatisfactory from that standpoint alone.

While there is a great variety of types of transformers built, the information in table I is representative. It is apparent therefore that little can be gained by reducing the major insulation levels of distribution transformers. This major insulation is the vital insulation of the transformer. It separates the user of electricity from contact with the high voltage lines and as such is recognized by the safety codes. It has been established at its present levels by many years of experience and usage. To experiment with these well established principles would be hazardous indeed. The transformer subcommittee made a wise choice in maintaining the insulation levels of distribution transformers and in increasing the test voltages to correspond.

Robert Treat (General Electric Co., Schenectady, N. Y.): There is necessarily some divergence of opinion among different individuals as to what standards ought to be—each person's opinion depending on his viewpoint, past experience, and the premises he selects from which to reason. In general, one find 2 viewpoints in the group drawing up these standards—that of the users and that of the manufacturers. Sometimes there are more differences of opinion among

the manufacturers themselves, or among the users themselves, than between the 2 groups as groups. The standards finally recommended are necessarily a compromise between these divergent opinions. It has been said that there is seldom any logic in a compromise. I presume the standards recommended in this paper are as logical a compromise as it is possible to achieve at the present time.

One part of the standards deals with tests to determine the impulse strength of transformers. When standards for impulse tests on transformers were first recommended about 2 years ago, there was some agitation to get them congealed in the Institute standardization rules immediately. Those who at that time felt it would be wiser to await the result of some experience before taking this step will be interested to note that already important changes in the impulse test procedure are recommended.

The purpose of impulse tests is to demonstrate that a transformer has a minimum impulse strength (under the specified test conditions) which can be used as a basis for protecting it against voltages of lightning origin. The second test specifies "a wave sufficient to flash over the bushing, provided standard bushings are used, and having a crest voltage bearing a definite relation to the 60 cycle test voltage." The comment under table II in the paper implies that this "definite relation" is to have a constant value for tests at all voltages. This requirement would seem to be a little dangerous unless it is very certain that the 60 cycle test voltages are so wisely selected that when multiplied by this "definite relation" they always produce the correct value of impulse test voltage!

Furthermore, it is conceivable that the 2 requirements of the second test; namely, that the impulse wave have a definite relation to the 60 cycle test voltage, and at the same time be sufficient to flash over the bushing, may at times be incompatible.

It is suggested that at least this portion of the recommended standards might well be given further consideration.

Portable Schering Bridge for Field Tests

Discussion of a paper by C. F. Hill, T. R. Watts, and G. A. Burr published in the January 1934 issue, pages 176–82, and presented for oral discussion at the insulation and protection session of the South West District meeting, Oklahoma City, Okla., April 24, 1935. This paper was also presented at the winter convention, New York, N. Y., January 25, 1934, and other discussion was published in the March 1934 issue, pages 478–81, April 1934 issue, pages 618–22, and September 1934 issue, page 1311.

G. W. Gerell (Union Electric Light and Power Co., St. Louis, Mo.): The experience of my company with the power factor testing of bushings is rather limited. In 1933 the 66 and 132 kv transformer and oil switch bushings on Westinghouse equipment at the Cahokia and Venice stations only were tested by means of the Schering bridge. In the fall of 1934 all bushings on the 66 and 132 kv system were tested. In addition quite a few 33 kv bushings in certain of the a-c distributing substations were included.

Table I—Bushing Power Factor Test Results

Bushing Voltage Class	Good		Deteriorated		Bad		Totals
	No.	% of Total	No.	% of Total	No.	% of Total	
132 Kv	134	78	18	10	21	12	173
73 Kv	287	72	62	16	48	12	397
37 Kv	215	68	43	14	59	18	317
Totals	636	72	123	13.5	128	14.5	887

The 1934 tests extended over a period of 7 weeks during which a total of 887 bushings were tested, including 173 bushings in the 132 kv class, 397 in the 73 kv class, and 317 in the 37 kv class.

It is assumed that the determination of the power factor of a bushing places that bushing in a definite classification with respect to its condition. These classifications may differ for the various types of bushings in use, depending upon method of construction, type of insulation used, and normal voltage rating. Tables giving the rating of bushing quality by the power factor indication have been published frequently in the technical press and will not be repeated here. These limiting power factor values, it should be noted, are usually based upon an ambient temperature of 20 degrees centigrade, increasing rapidly for higher temperatures and decreasing for lower. Considering these factors, the bushings tested on our system were classified according to voltage rating and power factor, with the results as shown by table I of this discussion.

It is to be observed from this tabulation that 14.5 per cent of the total number of bushings tested were found defective. By employing a number of rather simple methods we were able to restore a little less than half of these to normal power factor. About 25 per cent of the defective bushings were repaired by removing the old oil and refilling with new oil free from moisture and other foreign matter. Approximately 15 per cent of the defective bushings were repaired by circulating hot oil or air through the bushings for a period of several days. In some the high power factor was the result of an external faulty condition, which when removed resulted in a normal power factor test on the bushing. In table II are indicated the case histories of a number of these bushings which are of unusual interest.

The remaining defective bushings were either the condenser or solid porcelain type (mostly in the 37 kv class). The matter of the disposition of these was referred to the manufacturers.

Two condenser bushings, one testing 0.094 power factor at 26 degrees centigrade and the other 0.085 power factor at 13 degrees centigrade, were returned to the factory for test. The factories report stated that the first bushing could be repaired, but at a cost practically equal to the cost of a new bushing with trade-in allowance. It was decided therefore to purchase the new bushing. In the case of the second bushing the factory retest of power factor showed it to be less than 0.06 at 20 degrees centigrade, and further it was stated that any bushing of this particular construction is to be considered satisfactory if its power factor tests 0.06 or less at 20 degrees centigrade.

Practically all the remaining condenser bushings could therefore be reclassified, placing them into the "investigate" group. No further action will be taken on these bushings, at the present time, but they will be given greater consideration during the next routine test.

In regard to a number of solid porcelain bushings in the 37 kv class, instructions have been received from the manufacturer and materials necessary to rebuild them are available. By such expedients practically all of the defective bushings found on our system have either been restored to a serviceable condition or final action has been deferred until the next routine test.

The detailed analysis of any bushing testing high in power factor is seriously hampered by a lack of knowledge concerning the design and construction of that bushing. If the manufacturer would supply complete information on each type of bushing, and in addition, give detailed instructions as to methods of repair the testing procedure would be materially speeded up and the effectiveness of the testing would be increased. It is understood that at the present time at least one manufacturer is preparing such information for distribution to those interested.

Inasmuch as temperature apparently has such a pronounced effect on the power factor of a bushing, it would appear desirable to give it greater consideration before placing a bushing definitely into one of the 3 classes used to indicate its condition. Before this can be effectively done, accurate temperature-power factor curves should be made for *all* types of bushings usually found in service. These curves should be based on the test results for a considerable number of bushings of each type rather than for one or 2 of each type. Further, the wide variations found in the power factor of several bushings tested at great temperature differences as illustrated by case 4, table II, would indicate that the published curves are subject to certain inaccuracies or that there are other unknown factors influencing the power factor determination. Assuming that accurate curves can be constructed, there is still the question of the determination of the correct ambient temperature. Usually in testing transformer bushings the air temperature is one thing and the oil temperature is quite another, the actual bushing temperature lying somewhere between these 2 temperatures.

Under the present methods, testing transformer bushings requires usually that a portion of the oil in the transformer be dropped, manhole covers be removed, and leads on the terminal block or on the

Table II—Case History of Typical Defective Bushings

Case No.	Bushing Type	Rating, Kv	Power Factor as Found	Repairs Made	Power Factor After Repairs
1	Oil filled	132	0.036 at 19 deg C	Removed old oil from bushings and refilled with new oil testing less than 0.002 power factor	0.0105 at 21 deg C
2	Oil filled	132	0.056 at 21 deg C	Hot oil at 85 deg C circulated through bushing for 3 days	0.024 at 16 deg C
3	Oil filled	73	0.07 at 26 deg C	Hot air at 85 deg C circulated through bushing for 8 days	0.038 at 19 deg C
4	Oil filled	132	0.053 at 21 deg C	No repairs—retested later during cold weather	0.019 at 5 deg C
5	Oil filled	132	0.15 at 29 deg C	Removed old oil, flushed and refilled with new oil	0.01 at 19 deg C
6	Oil filled	73	0.045 at 12 deg C	Removed old oil and refilled with new oil	0.038 at 20 deg C
7	Condenser	37	0.087 at 25 deg C	Returned to factory for disassembling and drying out. Cost of repairs excessive—replaced with new bushing	0.03 at 22 deg C
8	Condenser	37	0.085 at 13 deg C	Returned to factory; test indicated 0.05 power factor at 25 deg C—will be returned to service	0.05 at 25 deg C

lower terminal of the bushing be removed before tests can be made. Exclusive of the time required to make the actual test, from 15 to 20 man-hours and considerable material are required just to prepare the unit for test. The test is then made by 2 men in from 10 to 15 minutes.

It is felt that the manufacturer of test equipment should devote considerable effort to this problem, and in this connection it is to be noted that one manufacturer of test equipment has facilitated the testing of transformer bushings in the development of a new attachment for their power factor test set which does not require that the transformer oil be lowered, or that the windings be disconnected from the bushings, provided that the bushing is equipped with an insulated flexible lead-in wire.

Since our experience has been limited in the main to the use of the Doble set, we naturally classified bushings as being good, deteriorated, or bad, in accordance with the experience and recommendations of the manufacturer. I do not believe though that bushing manufacturers would be inclined to agree in all cases with these recommendations which undoubtedly are quite conservative. The case of the condenser bushings, cited previously, is a forceful example of this disagreement.

Although it is appreciated that a hard and fast rule cannot be formulated to determine whether a bushing should be discarded or not, it appears desirable that an agreement should be reached here before power factor testing of bushings can proceed on an efficient basis.

There is one other point that has been rather confusing to us. That is the proper interpretation of results of power factor tests on oil. We made such tests, in conjunction with the regular bushing tests, on oil samples taken from oil switches, transformers, and metering equipment. Some of these results were difficult of interpretation or at any rate the remedial measures were uncertain. For example, oil testing high in dielectric breakdown but high in power factor might be high in acid and not be materially improved by the ordinary filtering treatment, or oil testing low in dielectric breakdown and high in power factor might have its breakdown improved by filtering but not necessarily its power factor. The question which suggests itself is whether under these conditions other treatment or replacement of the oil should be considered, or if other tests should be made to determine the exact cause for the high power factor. This is probably more of an oil problem than a power factor problem but is related to power factor testing in the interpretation of the power factor test results.

In general, we are of the opinion that the power factor testing of bushings can become quite effective in forestalling failures. The published experiences of operating companies will be of great value, and should give a detailed analysis of the reduction of bushing failures as a result of testing, including the case history of those bushings that failed. The degree of its effectiveness will also, in a large measure, be dependent upon the co-operative efforts of the bushing manufacturer to supply detailed constructional and test data on their products and upon the testing set manufacturers in developing new and simple means of performing the tests.

I. W. Gross (American Gas and Electric Co., New York, N. Y.): Discussion of this paper in the light of work done over a period of some 5 years on the American Gas and Electric Company system with the Doble insulation tester has previously been given by Philip Sporn and the writer. (ELECTRICAL ENGINEERING, April 1934, pages 618–22.) Since that time we have continued testing bushings and apparatus with that test set and believe that at this time it may be of interest to summarize briefly some of the results which have been obtained in our work. To review the history of bushing testing in our own company, we started testing oil circuit breaker bushings with the Doble test set in 1929, which is several years previous to the appearance of the authors' field test set. The statement in the authors' paper, therefore, that a portable instrument for the measurement of dielectric loss was not available previous to the Schering bridge described in their paper, for purchase and use by the power companies, is rather misleading to say the least. The possibilities of detecting in the field insulation troubles in bushings, oil circuit breakers, and the like, became so apparent from the results of these tests that we extended the work in 1931 to testing a group of 44 kv bushings which had been giving us considerable trouble, with the result that we found a major part of them defective. The indicated defects have since proved to be real sources of trouble on the system, and although we were convinced at the time of test that the bushings were defective, it was not economically feasible to replace the entire group at the time of test. In 1932 we started a yearly routine testing schedule on oil circuit breaker bushings in the voltage class of 22 kv and above. The results of a large part of this work, as well as the previous field work, were reported in 2 articles in the January 1934 *Electrical World* by Gross and Turner.

The results of the testing work started in 1932 proved so beneficial and resulted in such a decrease in bushing failures that the testing program was extended in 1933 by the use of a second testing set to include testing of instrument and power transformers in the 15 kv class and above. The test set and method of application have been so successful that we can today look over the past 2 years and say that very few bushing failures have occurred on apparatus which has been tested by this method since 1932. The very few bushing failures which have occurred have been on types of bushings on which it is known that defects may occur without warning due to the entrance of excessive moisture into the bushing. Analysis of the few cases of trouble encountered has indicated that the bushings which have failed were either in good condition at the time of test or were distinctly bad as indicated by tests and had not been removed by the operating force before failure occurred.

The test set used is the Doble insulation tester which applies a test voltage of 10,000 volts (or less if desired) and indicates directly the current and watts loss fed into the bushing circuit. The power factor is calculated by simple operation of a slide rule. In our use of the test set, experience has shown that the power factor alone tells only part of the story. We frequently obtain in cases of defective bushings as much if not more information from the direct indication of the watts loss as from the power factor alone. The charging current is rarely used to indicate or segregate trouble. In the use of this set, we have not found it necessary to remove the leads from the oil circuit breaker or transformer to the nearest disconnecting switch as the authors of the paper seem to feel is necessary with their set. By leaving the leads connected, we have on occasions found defective insulators in the circuit from the transformer to the disconnecting switch which would not otherwise have been found.

The watts loss measurement we have found of great benefit in segregating trouble and in fact in some cases in picking out defects which are not entirely apparent from the power factor reading alone. For example, if all bushings in a breaker show approximately the same power factor, there have been cases where the higher watts loss in one particular bushing indicates a defect which on analysis has actually been found and the fault removed.

So many different types of faults have been located in the field varying from internal defects in the bushing, deposits over the immersed section of bushings, defective bus insulators, defective oil

circuit breaker lift rods, cross bracing, tank insulation, oil, transformer windings, etc., that it would be impossible here to give a complete story of such troubles. We have, however, summarized for ready reference the results obtained during the past 2 periodic tests. For easy identification, we are referring to the "first test" as the first periodic test made on apparatus from 1932 to January 1, 1935. The expression "second test" applies to the second routine test of apparatus which had already received the first test. The extent of the testing work will be made clear by the following table of the number of bushings and transformers tested:

Apparatus Tested	Approximate Number	
	First Test	Second Test
Oil circuit breaker bushings	8,700	5,700
Power transformer bushings	2,700	6
Instrument transformer bushings	2,100	180
Approximate totals	13,500	5,886

Thus over 19,000 bushings are included in these 2 tests, together with the windings of the instruments and power transformers.

For purposes of preliminary analysis, the results have been segregated on a power factor basis into 3 classes: *A*, *B*, and *C*. Class *A* covers tests showing below 0.04 power factor, class *B* power factors from 0.04 to 0.05, and class *C* for power factors above 0.05. With this classification, the following table shows the results obtained on the 2 tests:

Class	Per Cent of Bushings Tested	
	First Test	Second Test
A	81.8	90.6
B	6.5	4.6
C	11.7	4.8

From this table it will be noted that when the second routine test was made, the good or class *A* bushings increased approximately 9 per cent. The class *B* or defective bushings had decreased about one third, and the class *C* or bushings marked for removal had been reduced to approximately half the value indicated on the first test.

The first routine test indicated clearly that a considerable number of bushings in service were defective or warranted removal. The second test also indicates that by giving proper attention to the results obtained in the first test, the defective and hazardous bushings had been materially reduced. Thus it is clear that by intelligent application of this power factor test method, defective and hazardous bushings can be materially reduced.

At the time tests are made in the field the men in charge are advised of bad conditions found and the recommendations for servicing. All field data sheets are sent into a central point for detailed study and analysis, and any conditions not caught by the test men are reviewed and further recommendations made, if necessary. A month or more after the tests have been made, a follow up check is made to see whether the recommendations made at the time of test have been carried out.

The summary record of field tests is made by transferring pertinent data on the field test sheets to a permanent card index so that from year to year the condition of any bushing or piece of apparatus can be readily traced from this card index.

The mere detection of defects in apparatus, bushings, or in the apparatus itself by field test is only the beginning of the removal of the trouble. To say that a bushing is defective at the time of test without locating the trouble by further tests or as a result of past experience is of little value. We have often chased down the indicated trouble and found that in practically every instance the trouble was exactly as diagnosed by the field test man. Experience of this kind often makes it advisable to note the apparent source of trouble at the time of test and leave it to the maintenance men to clear the trouble at their convenience if the fault is not of sufficient severity to warrant immediate action. Considerable more speed in testing can be gained in this way.

In chasing down trouble in the field we have found a variety of conditions from that of bushings with water actually running out of them when given a high voltage test, to conditions of water absorption by insulating members such as bushings, gaskets, insulating barriers, wooden lift rods, wooden bracing rods, deteriorated oil, open transformer windings, carbon deposits over the lower end of the bushing, and deteriorated bushing stud wrappings. The fact that the instrument is capable of giving a direct reading of watts loss in the test circuit has been of great value in segregating many of the troubles mentioned above which were actually found in the field.

At the time we inaugurated our routine testing of bushings in 1932, we estimated the saving possible by adopting a test program, balancing the cost of the bushing testing work against the probable bushing failures as a result of past experience. Revising our figures to conform to results obtained, we believe we are at present carrying on our bushing test work at a cost approximately equal to one-quarter of what it would cost us if we permitted bushing failures to take place in the field as they had been doing previously. The fact that we have had only a very few bushing failures among the bushings tested since our tests were first started, and then in some cases on bushings which had been recommended for removal, speaks volumes for the ability of the test set to detect trouble, the care exercised by the test men in getting and analyzing the data, and the careful attention given by the operating men in remedying defective conditions brought to their attention as a result of the tests.

Headquarters for A.I.E.E. October Meeting

THE electrical engineering building of Purdue University, West Lafayette, Ind., shown here, is to be headquarters for the meeting of the Institute's Great Lakes District (No. 5) which is to be held October 24 and 25, 1935. The program has been practically completed with 3 technical sessions, one student session, and a dinner meeting on Thursday evening. In addition to the subjects of technical papers mentioned in preliminary announcements in the June and July 1935 issue of ELECTRICAL ENGINEERING, papers on electronics, measurement of very high voltages, and general applications have been included on the program. Full details of the program are scheduled for inclusion in the September 1935 issue. The student session, scheduled for Friday morning, will be of considerable value both for students and for the engineers in attendance. An important function of membership in the Institute is the encouragement and assistance of the oncoming generation of electrical engineers, and it is hoped that many engineers will wish to participate in these sessions. Those who wish to stay over Saturday, October 26, may witness the football between Purdue University and Carnegie Institute of Technology, although reservations for both the game and for hotels should be made early. Purdue University, which lays claim to having the largest school of electrical engineering and the largest building devoted exclusively to electrical engineering in the United States, extends its welcome to all who may attend.

News

Of Institute and Related Activities

51st Annual Summer Convention Successfully Held on Cornell Campus

WITH a confirmed registration exceeding the average recorded at summer conventions during the past 15 years, the Institute's 51st annual summer convention was held June 24–28, 1935, on the Cornell University campus at Ithaca, N. Y. A comprehensive digest covering all the principal activities, including the several program and other innovations, is given on this and the following several pages. This news report, together with the technical papers, all of which have already been published in ELECTRICAL ENGINEERING, serves to convey to the entire membership, the essence of the convention activities.

ANNUAL BUSINESS MEETING

With Vice President R. B. Bonney of Denver, Colo., presiding on behalf of President J. Allen Johnson (absent because of illness) the annual business meeting, comprising the opening session of the convention, was held in Moot Court Room of Myron Taylor Hall, Monday morning, June 24, 1935. Paying tribute to the administrative authorities of Cornell University for their generosity in assuming the position of host to the Institute's 51st summer convention, Chairman Bonney called upon Dr. A. R. Mann, Cornell provost, who spoke on behalf of the university:

PROVOST MANN CONSIDERS CONVENTION ATTENDANCE A LIBERAL EDUCATION

"In view of the identification of university teaching and research with the technical and scientific fields into which university graduates go, it seems altogether appropriate that occasionally such an organization as the American Institute of Electrical Engineers should hold its meeting on a university campus. . . .

"By their terms, those sessions . . . devoted to education and research may appear at first glance to lie closer to the cultural purpose of the universities than is true of . . . technical sessions, but . . . in the fields of higher education every advance in science and technique is of direct and positive interest. Indeed, I should think that attendance upon such a convention as this . . . would in itself constitute a brief but highly intensive course in higher education.

"If the technical and industrial branches of engineering are to be most ably served by the classrooms and laboratories of science and engineering in the universities, there is needed at all times the most informed and mature judgment as to what is really fundamental in education in engineering and the sciences, and a frequent truing up of the educational curricula and methods to the significant trends in the use of the products of these institutions. With the growing tendency for large industries to provide their own post-graduate schools for specialized training in consonance with their own particular needs, the educational institutions may profit very greatly by the discriminating judgment of those who employ their products as to what constitutes the best foundation in the undergraduate years—how liberal in content, how broad in the fundamental sciences, how inclusive of technical developments—all, of course, in harmony with what is practicable. . . .

"We can never wisely overlook the fact that the function of colleges and universities is education—higher education—by means of many departments of knowledge, including the sciences and engineering subjects. Equally important do we regard university research. Industries may at times assess such research in terms of its value to the progress of industry. We also attach much importance to such values, but university research serves at least 2 other purposes of possibly greater importance to industry. One of these has to do with the advancement of fundamental knowledge in the sciences and the principles of engineering and the arts. . . . . The other high justification of university research is its contribution to the training of young men in science and of professional and technical men in science and in the professional and technical fields. Education in an atmosphere of research does for the student the most perhaps that the university can do for him. . . .

"Where a high development of research is lacking the educational process is lacking. It would surely redound greatly and directly to the advantage of the engineering industries in America if they should arouse among the leaders of industry themselves greater concern as to whether the colleges of engineering, from which they draw most of their fresh increments of technical men, are enabled to develop adequate research facilities and personnel. Because the great industrial organizations have developed their own research laboratories to a high degree and may for this reason feel less dependent upon the university laboratories, perhaps industrialists have given less thought than their own best interests warrant to the technical educational implications of a strong research atmosphere in our schools and colleges of engineering. . . . The human factor is paramount in industry as in all categories of life."

REPORTS OF THE BOARD OF DIRECTORS AND COMMITTEE OF TELLERS

In presenting a digest of the board of directors' report for the fiscal year ending April 30, 1935, National Secretary H. H. Henline mentioned among other things that a total of more than 2,600 had attended the 3 national conventions and 2 District meetings held by the Institute during that year, and that during the same period 61 Institute Sections had held a total of 521 meetings, and 117 Branches had held 986 meetings, amounting to more than 1,500 meetings held this past year in many parts of the United States, Canada, and Mexico. The Sections held the largest total number of meetings ever reported for any fiscal year. Other details may be found in full in the report as published in ELECTRICAL ENGINEERING June 1935, pages 674–5.

In accordance with the by-laws and with the report of the committee of tellers as presented, Chairman Bonney declared the election of the following members, each to take office August 1, 1935:

President:

E. B. Meyer, chief engineer, Public Service Electric and Gas Company, Newark, N. J.

Vice Presidents:

W. H. Harrison, vice president, Bell Telephone Company of Pennsylvania, Philadelphia, Pa.
Mark Eldredge, chief engineer, Memphis Power and Light Company, Memphis, Tenn.
R. H. Fair, plant operations supervisor, Northwestern Bell Telephone Company, Omaha, Neb.
N. B. Hinson, chief engineer, Souther California Edison Company, Los Angeles, Calif.
C. V. Christie, professor of electrical engineering and chairman, department of electrical engineering, McGill University, Montreal, Que.

Directors:

C. R. Jones, northeastern transportation manager, Westinghouse Electric and Manufacturing Company, New York, N. Y.
W. B. Kouwenhoven, professor of electrical engineering and assistant dean, The Johns Hopkins University, Baltimore, Md.
G. C. Shaad, dean, School of Engineering and Architecture, University of Kansas, Lawrence Kans.

National Treasurer:

W. I. Slichter, professor of electrical engineering, Columbia University, New York, N. Y.

The board of directors for the administrative year beginning August 1, 1935, consists of these newly elected officers, together with the following hold-over officers: J. Allen Johnson (retiring president), Buffalo, N. Y.; J. B. Whitehead, Baltimore, Md.; F. O. McMillan, Corvallis, Ore.; F. J. Meyer, Oklahoma City, Okla.; G. G. Post, Milwaukee, Wis.; R. H. Tapscott, New York, N. Y.; W. H. Timbie, Cambridge, Mass.; F. Malcolm Farmer, New York, N. Y.; N. E. Funk, Philadelphia, Pa.; H. B. Gear, Chicago, Ill.; P. B. Juhnke, Chicago, Ill.; G. A. Kositzky, Cleveland, Ohio; Everett S. Lee, Schenec-

Future AIEE Meetings

Pacific Coast Convention,
Seattle, Wash., Aug. 27–30, 1935

Great Lakes District Meeting,
West Lafayette, Ind., Oct. 24–25, 1935

Winter Convention,
New York, N. Y., Jan. 28–31, 1936

North Eastern District Meeting,
New Haven, Conn., May 1936

Summer Convention,
Los Angeles, Calif., June 22–26, 1936

Middle Eastern District Meeting,
Akron, Ohio (date to be determined)

tady, N. Y.; A. H. Lovell, Ann Arbor, Mich.; L. W. W. Morrow, New York, N. Y.; and A. C. Stevens, Schenectady, N. Y.

Thereupon Chairman Bonney pinned the president's badge upon Mr. Meyer's coat lapel, introducing him to the membership as "one who has been a very faithful member and who has worked hard on a number of Institute committees for many years." The essence of President-Elect Meyer's response is published on page 807 of this issue.

The report of the tellers' committee on the vote for the proposed amendments to the constitution which had been previously submitted to the membership by mail, was made. These amendments called for modification of the election procedure to permit the holding of the meeting of the national nominating committee during the winter convention in January instead of early in December, with the resulting later publication of information concerning the nominations, and later election, but without changing the date of announcement or the date on which officers take office. The tellers' report showed that the 6 amendments to the constitution necessary for making these changes were approved by the membership, and Chairman Bonney declared them so approved.

The new sentences of the constitution, all in Article VI, and giving in parentheses the dates in effect before the recent changes, are:

Section 30, second sentence:
"The national nominating committee shall name on or before January 31 (previously December 15) of each year, one or more candidates for president, national treasurer, and the proper number of directors, and shall include in its ticket such candidates for vice presidents as have been named by the nominating committees of the respective Geographical Districts, if received by the national nominating committee when and as provided in the by-laws; otherwise the national nominating committee shall nominate one or more candidates for vice president(s) from the District(s) concerned."

Section 32, first sentence:
"During the first week in April (previously March) of each year the national secretary shall mail to all qualified voters an official ballot on which are to be listed all eligible candidates, nominated as provided in Sections 30 and 31."

Section 32, last sentence:
"The outer envelope of either class shall be identified by the name of the sender on its face, shall be sealed, and, in order to be counted, shall reach the national secretary not later than the first day of June (previously May)."

Section 33, first sentence:
"The president, during the month of May (previously March) shall appoint, subject to the approval of the board of directors, 7 Fellows, Members or Associates, not members of the board of directors or of the national nominating committee, to constitute the committee of tellers."

Section 33, second sentence:
"Any Fellow, Member, or Associate not a member of the board of directors or of the national nominating committee who shall deliver to the national secretary on or before the first day of May (previously March) a written petition signed by at least 20 Fellows, Members, or Associates, stating their desire that he be a member of the committee of tellers, shall also be a member of that committee, provided that the aforesaid signatures shall not have appeared on another similar petition."

Section 34, first sentence:
"The committee of tellers shall meet at the office of the Institute as soon after the first day of June (previously May) as possible, and shall receive, unopened, all ballots from the national secretary, who shall also make to it a written report of the number of ballots received on and before, and after, the first day of June (previously May)."

Institute Prizes Presented

The report of the national committee on award of Institute prizes, as published on page 677 of the June 1935 issue of Electrical Engineering, was read by R. N. Conwell, chairman of the committee, and the corresponding presentations were made by Chairman Bonney.

The annual District meeting of the North Eastern District having been dispensed with in favor of the summer convention at Ithaca, the report of the District prize award committee was presented by District Secretary A. C. Stevens, as published in Electrical Engineering, page 677 of the June 1935 issue, and page 785 of the July 1935 issue. District prizes were presented accordingly to the winners present.

Message From President Johnson

Just as the annual business meeting was drawing toward a close, a letter arrived via special delivery containing a statement from retiring president J. Allen Johnson of Buffalo, N. Y., whose illness prevented his attendance. Chairman Bonney read the letter, the full text of which was published on page 785 of the July 1935 issue of Electrical Engineering.

Lamme Medal for 1934 Presented to H. E. Warren

"For outstanding contributions to the development of electric clocks and means for controlling central station frequencies," the seventh in the series of the Institute's Lamme Gold Medals was presented during the annual business meeting to H. E. Warren (A'02) president of the Warren Telechron Company of Ashland, Mass. A brief biographical sketch of Medalist Warren may be found on page 351 of the March 1935 issue of Electrical Engineering.

Other Lamme Medal Awards

The 6 previous awards of the A.I.E.E. Lamme Medal have been made as follows:

1928—To A. B. Field (A'03, F'13) consulting engineer, Manchester, Eng., for "the mathematical and experimental investigation of eddy current losses in large slot-wound conductors in electrical machinery."

1929—To R. E. Hellmund (A'05, F'13) chief engineer, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., for "his contributions to the design and development of rotating electrical machinery."

1930—To W. J. Foster (A'07, F'16) consulting engineer, retired, General Electric Company, Schenectady, N. Y., for "his contributions to the design of rotating a-c machinery."

1931—To Guiseppe Faccioli (A'04, F'12) deceased, January 13, 1934, formerly associate manager of the Pittsfield (Mass.) Works of the General Electric Company, for "his contributions to the development and standardization of high-voltage oil-filled bushings, capacitors, lightning arresters, and numerous other features in high-voltage transformers and power transmission."

1932—To Edward Weston (A'84, M'84, member for life and past-president) chairman of the board of the Weston Electrical Instrument Corporation, Newark, N. J., for "his achievements in the development of electrical apparatus, especially in connection with precision measuring instruments."

1933—To L. B. Stillwell (A'93, M'92, F'12, member for life, and past-president) consulting engineer, New York, N. Y., for "his distinguished career in connection with the design, installation, and operation of electrical machinery and equipment."

H. E. Warren (right) receiving the 1934 Lamme Medal of the A.I.E.E. during the summer convention at Ithaca, N. Y., from Vice President R. B. Bonney. Prof. C. L. Dawes (left) made the address outlining the career of Lamme Medalist Warren

The Institute's Lamme Medal was established by provision of the will of Benjamin Garver Lamme (deceased July 8, 1924) for the encouragement and recognition of "meritorious achievement in the development of electrical apparatus or machinery." By Mr. Lamme's will, 2 other similar bequests were made, one to Ohio State University, and one to the Society for the Promotion of Engineering Education. The Lamme Medal of Ohio State University, to be awarded a graduate of one of the technical departments for meritorious achievement in engineering or the technical arts was presented for 1935 to George A. Burrell of Burrell-Mase Engineering Company, Pittsburgh, Pa. The eighth Lamme Medal of the S.P.E.E. was awarded to William E. Wickenden (A'07, M'13) Case School of Applied Science, Cleveland, Ohio.

Dawes Outlines Warren's Work

In his address covering the life of Lamme Medalist Warren, Prof. C. L. Dawes of Harvard University traced the course of Mr. Warren's work from the time of his early and successful efforts in the manufacture of battery driven electric clocks through the various difficulties incident to the development and successful merchandising of the idea of universal synchronized electric time. Of Mr. Warren and his work, Professor Dawes said in part:

"His chief contribution (to the advancement of the art of electrical engineering) consists in the development of methods for securing accurate timing by means of the current taken from ordinary central station service wires. . . . Two distinct elements: first, providing a synchronous motor timing device by which accurate timing can be had wherever regulated a-c power service is available, and second, devising means by which the frequency of power systems can be so accurately controlled that accurate timing is possible and the operation and interconnection of power systems are greatly simplified. . . .

"Thus, thanks to Mr. Warren, the public is now provided with clocks and other timing devices which are much less expensive . . . and more accurate. . . . Mr. Warren's inventions also have contributed directly to the electric power industry itself. . . . Constant frequency enhances the value of central station service. Many industrial processes, such as papermaking and some textile operations, are sensitive to changes in speed and hence frequency; with the frequency exactly constant, a better and more uniform product is assured. . . .

"In considering Mr. Warren's achievements and those of the donor of this medal, I cannot but help seeing a correlation between the 2. Mr. Lamme was a pioneer designer of the polyphase alternator which made the early a-c power networks possible, and after some 40 years the same general types of alternator and power system are still in use today. Mr. Warren is the pioneer who provided means by which the speeds of such alternators may be accurately regulated, thus permitting these a-c networks to operate at a constant frequency and thereby providing means for widespread power interconnection as well as increasing the usefulness of a-c service to the public at large. Hence to me it seems that Mr. Warren's contribution has in reality been the carrying to further perfection the earlier contributions that were made by Mr. Lamme himself."

H. E. Warren Cites Anecdotes

In his remarks, offered in response to Professor Dawes's address, Medalist Warren presented reminiscences covering various phases of his life work, citing as his first important work, the invention of an instrument for measuring temperature at a distance, for which he was granted a patent soon after his graduation from Massachusetts Institute of Technology in 1894; he also stated that his next work had to do with street and interurban railway construction and hydraulic governor design. Of his work he said in part:

"None of these positions had much of an element of timekeeping or of clocks in it, but I started working on electric clocks as a hobby . . . so in my spare time I worked on this idea, and tried out different designs of electric clocks.

" . . . Prior to 1916 the electric companies were selling 3 kinds of service—light, power, and heat. Now they are practically all selling light, power, heat, and time service, all . . . over the same wires. They are all distinct, all have qualities and values of their own, and that has been the result of this development.

"Now this work that I have done . . . seems to me to be nothing more than an extension of the trail of engineering progress into new territory. No one person can mark but a small portion of the long trail that goes back into the dim past and continues on indefinitely into the future. Gladly would I acknowledge the aid I have received from the pioneer scientists and engineers and inventors who have marked this trail up to the point where my work began. . . . In addition to these, . . . I would also include those who helped me in my early experiments, and some of those officials and engineers of the power companies to whom I was able to show the picture that was in my mind and who had sufficient enthusiasm to persuade their companies to give the aid and the co-operation without which I could not possibly have succeeded."

The Lee golf trophy, presented by the late Past-President W. S. Lee for 36-hole lowest net score. The winner's name is engraved on the 14-inch cup, which must be won twice for permanent possession. A. H. Sweetnam of Boston, Mass., won at Ithaca, this being his first winning

The Lamme Medal of the A.I.E.E., established by the bequest of Benjamin Garver Lamme (deceased July 8, 1924), chief engineer of the Westinghouse Electric and Manufacturing Company. According to the provisions of the bequest, a gold medal accompanied by a replica in bronze is awarded each year to a member of the Institute "who has shown meritorious achievement in the development of electrical apparatus or machinery." The Lamme Medal for 1934 was presented to H. E. Warren, president of the Warren Telechron Company, Ashland, Mass., during the summer convention at Ithaca "for outstanding contributions to the development of electric clocks and means for controlling central station frequency"

Other Program Features

Technical Sessions

The technical program at Ithaca was somewhat heavier than the average for summer conventions, embracing 10 technical sessions which accommodated the presentation and discussion of 39 papers and the presentation of 2 special addresses, all in accordance with the program as published on page 561 of the May 1935 issue of

ELECTRICAL ENGINEERING and amended on page 668 of the June issue.

All papers presented at the convention were published in advance in ELECTRICAL ENGINEERING in the February, March, April, May, and June issues, and thus made available to the entire membership of the Institute. Dr. D. B. Steinman's special address "Registration of Engineers" is published elsewhere in this issue, and Takeshi Takei's special address "The Electrochemical Industries in Japan" probably will be published in a future issue.

ATTENDANCE

Inasmuch as the holding of a summer convention of the Institute on a university campus was without precedent, advance prediction of convention registration and attendance was difficult, and the ultimate total was in doubt until after the final day's sessions had closed, because each day brought in a substantial new group of registrants. Analysis of the attendance figures included in the 2 accompanying tabulations and comparison of these with similar figures published in previous years reveals several interesting facts. For lack of space these are left to the reader to deduce. However, it suffices to say that the final officially recorded and checked registration of 904 persons is some 11 per cent above the average recorded attendance at summer conventions for the past 15 years, in spite of the fact that Ithaca is far removed from any large center of population.

ENTERTAINMENT

In addition to bridge parties and miscellaneous inspection trips through campus and other nearby points, including points of scenic beauty, several well arranged general entertainment features served to round out the convention program in a very satisfactory manner. The first general affair was the reception for the president-elect which was held in Willard Straight Hall Monday evening, followed by a dance. The attendance at this function was some 600. Next, there was the picnic outing held Tuesday afternoon and evening at picturesque Taughannock State Park on the shores of Cayuga Lake, which drew an attendance of 539. That same evening back on the campus at Willard Straight Hall there was presented an effective informal musicale at which some 400 were in attendance, with an overflow audience on the terrace outside.

A large part of Wednesday was given over to a well organized inspection trip through the Corning Glass Works at Corning, N. Y. Some 200 women made the 40-odd mile trip in the morning, and, after being conducted through the glass works, were the guests of the Corning Glass Works at bridge and golf, held at the Corning Country Club that afternoon. More than 350 men left Ithaca following the morning technical session, were conducted through the glass works during the afternoon, and were the guests of the Corning Glass Works at a buffet dinner held at the Baron Steuben Hotel early in the evening. All visitors were shown typical operation of the glass plant, from bulb blowing and thermometer tube drawing to the manufacture of baking ware. A focal point of particular interest was the 200-inch telescope reflecting mirror cast in December 1934 for the California Institute of Technology, Pasadena, and now being gradually reduced in temperature in a special electric annealing kiln. This affair was excellently handled by a special committee of local men and women.

A putting contest held at the Ithaca Country Club Thursday morning, and the general convention banquet and dance held at Willard Straight Hall Thursday evening, brought the convention's entertainment program to a close The banquet attendance was 388.

GOLF

Principal sports event was the annual golf tournament and other related and officially recognized events, which were played on the Ithaca Country Club course which conveniently adjoins the Cornell campus. Many prizes were offered by the local committee in addition to the official Lee and Mershon trophies. As was the case last year at Hot Springs, competition was intensified by the fact that several were playing with the hope of getting their names on one or the other of these trophies for the second time.

For the Mershon trophy competition, a total of 16 players qualified. This qualifying group was reduced subsequently by match play to a final round played Thursday, June 27, between Helwig and Keiffer, with the result:

Winner—L. R. Keiffer, Cleveland, Ohio; 1 up
Runner-up—F. C. Helwig, Toledo, Ohio

Mr. Keiffer won the Mershon trophy in 1932, and thus came into permanent possession of it by virtue of his success at Ithaca. The names that appear on this cup as it will be held by Mr. Keiffer are: L. R. Keiffer, Cleveland, Ohio, 1932; H. W. Eales, Chicago, Ill., 1933; G. A. Kositzky, Cleveland, Ohio, 1934; L. R. Keiffer, Cleveland, Ohio, 1935. The present trophy is the second cup donated by Past-President Mershon, the first having been won permanently in 1931 by L. F. Deming of Philadelphia, Pa., after having withstood competition since 1912. This trophy was offered for competition by match play on a handicap basis, subject to permanent possession by virtue of 2 winnings by an Institute member.

The Lee trophy, presented by the late

The Mershon golf trophy, which passed into the permanent possession of L. R. Keiffer of Cleveland, Ohio, after his second winning at summer convention golf tournaments. Mr. Keiffer won at Cleveland, Ohio, in 1932, and at Ithaca, N. Y., in 1935. The previous cup donated by Past-President Mershon remained in competition from 1912 to 1931 before being permanently won. Competition for this trophy is by match play on a handicap basis

Past-President W. S. Lee in 1932, is competed for annually on the basis of lowest net score for 36 holes, and must be won twice by the same player for permanent possession. The results for the 36-hole medal play at Ithaca were:

Winner—A. H. Sweetnam, Boston, Mass.; 166–16, 134.
Runner-up—L. W. McCullough, New York, N. Y.; 173–19, 135.

Names now appearing on the Lee trophy

Table II—Summer Convention Attendance During Recent Years

1935	Ithaca, N. Y.	* (1)	904
1934	Hot Springs, Va.	(4)	351
1933	Chicago, Ill.	(5)	968
1932	Cleveland, Ohio	(2)	1,022
1931	Asheville, N. C.	(4)	525
1930	Toronto, Ont., Canada	(10)	1,110
1929	Swampscott, Mass.	(1)	1,000
1928	Denver, Colo.	(6)	500
1927	Detroit, Mich.	(5)	1,200
1926	White Sulphur Spgs., W. Va.	(2)	350
1925	Saratoga Spgs., N. Y.	(1)	900
1924	Chicago, Ill.	(5)	750
1923	Swampscott, Mass.	(1)	1,616
1922	Niagara Falls, N. Y.	(1)	950
1921	Salt Lake City, Utah	(9)	426
1920	White Sulphur Spgs., W. Va.	(2)	314

* District numbers in parentheses.

Table I—Analysis of Attendance at 1935 Summer Convention, Ithaca, N. Y.

Classification	Dist. 1	Dist. 2	Dist. 3	Dist. 4	Dist. 5	Dist. 6	Dist. 7	Dist. 8	Dist. 9	Dist. 10	Foreign	Totals
Members	223	108	109	14	45	4	11	7	6	7		534
Men guests	41	27	20	2	6	–	3	1	1	2	1	104
Women guests	87	71	60	5	13	2	10	10	2	6	–	266
Totals	351	206	189	21	64	6	24	18	9	15	1	904

The new Mershon tennis trophy, donated by Past-President Mershon, to replace the trophy which he had donated in 1927, and which passed in 1934 into the permanent possession of E. F. Lopez of Mexico City, after having been won by him at 2 summer conventions. The new trophy, some 35 inches in height, will remain at Institute headquarters. Allen O. White, winner at Ithaca, is the first to have his name engraved on the cup

are: C. H. Teskey, Cleveland, Ohio, 1932; G. R. Canning, Cleveland, Ohio, 1933; F.M. Craft, Atlanta, Ga., 1934; A. H. Sweetnam, 1935.

District team competition, on the basis of 36-hole medal play, was entered into by teams from Districts 1, 2, and 3. The team from District 2 won the event as follows:

F. C. Helwig, Toledo, Ohio, 159; G. V. Smith, Mansfield, Ohio, 173; G. R. Canning, Cleveland, Ohio, 174; and G. A. Kositzky, Cleveland, Ohio, 177.

TENNIS

Tennis competition was not so widespread as was golf, but spectators were treated to lively sets. In addition to the men's tournament, there was sufficient interest in tennis among the women to justify a women's tournament which was won by Mrs. F. J. Groat of Brooklyn, N. Y., with Miss Helen Kroger of Covington, Ky., as runner-up. For the men's tennis tournament, Past-President Mershon in 1927 donated a trophy available to Institute members, the winner each year being recognized by having his name engraved on the cup and receiving a photograph of it. That trophy, subject to permanent possession after a second winning, passed in 1934, at Hot Springs, Va., into the permanent possession of Delegate E. F. Lopez of Mexico City, Mex. A second and larger trophy was donated this year by Past-President Mershon to be competed for under the same rules as those which governed competition for the first cup, with the exception that the cup should always remain at Institute headquarters, with the names of the winners engraved upon it. The winner of the Ithaca tournament, and the first to have his name engraved on the new trophy, was Allen O. White of Washington, D. C.

E.C.P.D. Initiates Plan to Accredit Eastern Schools

The Engineers' Council for Professional Development, sponsored by the leading national engineering societies, the engineering educators, and the engineering examiners announced during July the inauguration of its program for accrediting engineering schools in New England and the Middle Atlantic States. The program will be offered to the other parts of the country after a trial period in these 2 regions. Notice is being sent to the presidents of all degree-granting engineering schools in the 2 areas advising them that the E.C.P.D. stands ready to receive requests for consideration of particular engineering curricula which the schools may wish to submit. The plan to be followed in the accrediting procedure was outlined in ELECTRICAL ENGINEERING for February 1935, pages 249–50, and March 1935, page 343.

Through the E.C.P.D. committee on engineering schools, regional subcommittees have been organized to visit each institution requesting recognition for its curricula. The visits by these committees will begin early in the fall and it is expected that the accrediting in these regions will be well under way before the first of the year. The plans and procedures will be considered in the light of the experience in carrying out the accrediting process in these regions, and with such modifications as seem desirable, the plan will then be offered to the other parts of the country.

Accrediting is necessary at the present time for a number of reasons, the most urgent of which is the fact that a majority of the states have enacted laws for the licensing of engineers, and that licensing procedure requires a list of accredited colleges whose graduates may submit evidence of their graduation in partial fulfillment of the requirements of licensure. The Engineers' Council for Professional Development is undertaking this work because it is the only body which represents all of the interested groups: the engineering schools, the state licensing boards, and the national engineering societies.

While the primary purpose of E.C.P.D. through its committee on engineering schools is to identify those institutions which offer professional curricula in engineering worthy of recognition as such, in longer range the purpose is to aid in promoting the best interests of engineering education and to raise the general level of its effectiveness. Emphasis will be given to quality of work, rather than to statistical information, to a greater degree than in former accrediting procedures. No hard and fast prescriptions are laid down for curricula, physical facilities, investments or expenditures, or other specific points relating to a given institution, although all of these, and others, will be taken into account in appraising the institution as a whole.

Great progress has been made in certain of the professions in raising the standards of their professional schools. The most notable of these is the medical profession. It is believed that this program of E.C.P.D. is an important part of the broader plan for enhancing the status of the engineering profession.

The constituent organizations of the Engineers' Council for Professional Development are: American Society of Civil Engineers, American Institute of Mining and Metallurgical Engineers, The American Society of Mechanical Engineers, American Institute of Electrical Engineers, Society for the Promotion of Engineering Education, American Institute of Chemical Engineers, and National Council of State Boards of Engineering Examiners.

Final Announcement—The Pacific Coast Convention

All plans for the Pacific Coast Convention of the A.I.E.E., which will be held in Seattle, Wash., August 27–30, 1935, have been completed. Headquarters will be in the Olympic Hotel, one of the finest and one of the most modernly equipped hotels in the northwest. The convention committee has arranged an excellent program which provides for the presentation and discussion of timely technical papers, yet there is ample opportunity for sports, trips, and recreation, as well as other specially arranged trips for the visiting women. The Puget Sound area is noted for its scenic beauty, and the convention, which will be held during part of the week preceding Labor Day, affords members and their guests advantages for several good vacation days.

The various features of the convention were announced in ELECTRICAL ENGINEERING for July 1935, pages 783–4. The tentative technical program listed therein is complete with the addition of a paper "Off-Peak Control of Water Heater Load" by F. M. Starr, of General Electric Company. This paper will not be published in ELECTRICAL ENGINEERING but copies will be supplied at the convention by the author. In regard to entertainment and trips, additional information now available is as follows:

ENTERTAINMENT

The previously announced salmon fishing contest which is scheduled on Wednesday, August 28, at 4:00 a.m., will be an unusual attraction. Contestants will leave the Olympic Hotel one hour before sunrise. The salmon will be running up the river then and the fishing will be in Seattle Harbor at the mouth of the Duwamish River. The visitors that get a large salmon on their line

will have a real thrill. A prize will be awarded for the largest salmon.

Also, the boat ride for the women in the afternoon will be another unusual feature. The "Sightseer" will leave Pier 3 at 2:00 p.m. and the trip will be made in the opposite direction from that previously announced, ending at Leschi Dock, where automobiles will meet the boat and return the party to the Olympic Hotel.

Inspection Trips

The following additional city trips have been arranged:

Ship-to-shore radio station—The Pacific Telephone and Telegraph Company

Distribution facilities—City of Seattle, Lighting Department

In connection with the suggested trip at the close of the convention to the Skagit River development of the City of Seattle lighting department, the northwestern section of the International Association of Electrical Inspectors will meet in Seattle the week following Labor Day. They are arranging a trip to the Skagit River development which takes 2 days, Sunday and Monday, following our convention, so it is possible that some of our people will find it desirable to take this trip with this larger party. The city of Seattle maintains a railroad from the Skagit River development toward Seattle as far as Rockport, which is about 100 miles from Seattle. While the convention transportation committee is not arranging to supply transportation to Rockport, it is possible that some of the Seattle members will also be making the trip and can accommodate some of the visitors. The cost of the 2 day trip on the city's railroad from Rockport, including lodging and meals, is $2.50. If anyone wants to go Saturday and return on Monday, making a 3 day trip, the additional cost is $1.50.

Reservations and Registration

Members and guests should fill in and mail promptly the return postcard sent with the announcement to members in the nearby territory. The registration and information desk will be opened on Monday, August 26, and will be maintained throughout the convention. All members and guests are requested to register promptly upon arrival and receive their badges.

1935 Lamme Medal Nominations Due Nov. 1

In fulfilment of by-law requirements, a second posting is hereby given to the necessity of all nominations for the Lamme Medal for 1935 being submitted not later than November 1, 1935. (See Electrical Engineering, June 1935, pages 669–70.) Presentation of the 1934 Lamme Medal was made to Henry E. Warren (A'02) president of the Warren Telechron Company, Ashland, Mass., at the opening session of the Institute's recent summer convention at Cornell University.

A.I.E.E. Directors Meet During Summer Convention

The regular meeting of the board of directors of the American Institute of Electrical Engineers was held at Cornell University, Ithaca, N. Y., on June 26, 1935, during the annual summer convention of the Institute.

Present: *Past-President*—J. B. Whitehead, Baltimore, Md. *Vice Presidents*—R. B. Bonney, Denver, Colo.; F. M. Craft, Atlanta, Ga.; F. O. McMillan, Corvallis, Ore.; F. J. Meyer, Oklahoma City, Okla.; G. G. Post, Milwaukee, Wis.; R. W. Sorensen, Pasadena, Calif.; and W. H. Timbie, Cambridge, Mass. *Directors*—L. W. Chubb, East Pittsburgh, Pa.; F. Malcolm Farmer, New York, N. Y.; H. B. Gear, Chicago, Ill.; B. D. Hull, Dallas, Tex.; P. B. Juhnke, Chicago, Ill.; G. A. Kositzky, Cleveland, Ohio; Everett S. Lee, Schenectady, N. Y.; L. W. W. Morrow, New York, N. Y.; A. C. Stevens, Schenectady, N. Y.; and H. R. Woodrow, Brooklyn, N. Y. *National Treasurer*—W. I. Slichter, New York, N. Y. *National Secretary*—H. H. Henline, New York, N. Y. By invitation: *Past-Presidents*—A. W. Berresford, P. M. Lincoln; *officers-elect*—E. B. Meyer, W. H. Harrison, C. R. Jones, W. B. Kouwenhoven.

In the absence of President Johnson, because of illness, Senior Vice President R. B. Bonney presided.

The minutes of the board of directors meeting of May 20, 1935, were approved.

Reports were presented and approved of meetings of the board of examiners held May 29 and June 19, 1935. Upon the recommendation of the board of examiners, the following actions were taken: 2 applicants were transferred to the grade of Fellow; 15 applicants were elected and 13 transferred to the grade of Member; 105 applicants were elected to the grade of Associate; 143 Students were enrolled.

The finance committee reported disbursements for the month of June amounting to $19,291.47. Report approved.

Report was made of the following appointments of representatives of the Institute made upon the recommendation of the standards committee: W. M. Dann to the sectional committee on transformers; A. M. Opsahl to the sectional committee on code for lightning protection; A. E. Kennelly, V. Karapetoff, C. H. Sharp, and W. I. Slichter to the sectional committee on electric and magnetic magnitudes and units.

H. P. Charlesworth was reappointed a representative of the Institute on the board of trustees of United Engineering Trustees, Inc., for the term of 4 years beginning in October 1935. L. A. Ferguson was reappointed to the Commission of Washington Award for the 2-year term beginning August 1, 1935. Dean Vannevar Bush was nominated for appointment to the division of engineering and industrial research of the National Research Council. President-elect E. B. Meyer was appointed a representative of the Institute upon the American Engineering Council for the term of one year, beginning August 1, 1935, to succeed J. Allen Johnson, retiring president.

The board accepted, with appreciation, from the American Telephone and Telegraph Company 2 copies of a sound motion picture of past-presidents of the Institute prominent in communication, entitled "Engineers of Speech," one copy for the Institute's archives, and the other for presentation to The Institution of Electrical Engineers (Great Britain). This film includes a reproduction of the joint meeting held during the A.I.E.E. winter convention of 1928 with The Institution of Electrical Engineers by means of the transatlantic radiotelephone channel.

Approval was given to the plan of the Engineers' Council for Professional Development for the establishment of a central certification agency as proposed by the E.C.P.D. committee on professional recognition.

An invitation from the Société Française des Electriciens to nominate a candidate for the Mascart Medal for 1936 was referred to the president and the chairmen of the Edison Medal and Lamme Medal Committees with power to act.

Appreciation was expressed, by resolution and otherwise, of the effective services of the general convention committee and its subcommittees, of the ladies entertainment committee, and of the hospitality extended by Cornell University, in connection with the 1935 summer convention of the Institute.

A resolution was adopted expressing to President Johnson the board's sympathy on account of his illness during the past several months, its sense of loss caused by his enforced absence from board meetings and other events, and its appreciation of his frequent inspiring messages to the membership and his attention to all the important duties of his office.

Other matters were discussed, reference to which may be found in this or future issues of Electrical Engineering.

Irving Langmuir Honored by A.S.M.E.

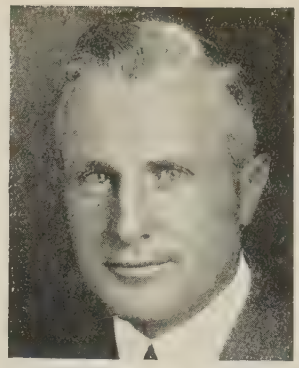
The Holley Medal for 1934 was awarded on June 20, 1935, at the semi-annual meeting of the American Society of Mechanical Engineers at Cincinnati, Ohio, to Dr. Irving Langmuir, associate director of the General Electric Research Laboratory, for his contributions to science and engineering, especially in the development of the gas-filled incandescent lamp, of the thoriated filament for thermionic emission, of atomic-hydrogen welding, of phase-control operation of the grid-controlled gas-filled tube, and in fundamental research in oil films.

The Holley Medal was instituted and endowed in 1924 by George I. Rockwood, past vice president of the A.S.M.E., to be bestowed for some great and unique act of genius of engineering nature that has accomplished a great and timely public benefit. It was awarded to Hjalmar Gotfried Carlson in 1924; to Elmer Ambrose Sperry in 1928; and to Baron Chuzaburo Shiba in 1929.

Dr. Langmuir also was recently elected to foreign membership in the Royal Society, England. Foreign membership, considered one of the highest honors that can be bestowed by British scientists on fellow workers in other countries, is limited to 50 persons throughout the world.

Newly Elected A.I.E.E. National Officers

N. B. HINSON
Vice President
Chief Engineer, Southern California Edison Company, Los Angeles, Calif.



W. H. HARRISON
Vice President
Vice President, Bell Telephone Company of Pennsylvania, Philadelphia, Pa.

MARK ELDREDGE
Vice President
Chief Engineer, Memphis Power and Light Company, Memphis, Tenn.

C. V. CHRISTIE
Vice President
Professor of Electrical Engineering and Chairman, Department of Electrical Engineering, McGill University, Montreal, Quebec

E. B. MEYER
President
Chief Engineer, Public Service Electric and Gas Company, Newark, N. J.

R. H. FAIR
Vice President
Plant Operations Supervisor, Northwestern Bell Telephone Company, Omaha, Neb.

G. C. SHAAD
Director
Dean, School of Engineering and Architecture, University of Kansas, Lawrence, Kans.

W. B. KOUWENHOVEN
Director
Professor of Electrical Engineering, and Assistant Dean, Johns Hopkins University, Baltimore, Md.

C. R. JONES
Director
Eastern Transportation Manager, Westinghouse Electric and Manufacturing Company, New York, N. Y

Officers, Delegates, and Members Hold Annual Conference at Ithaca, N. Y.

SPONSORED jointly by the Sections committee and the committee on student Branches, the regular conference of officers, delegates, and members of the Institute was held in the Moot Court Room of Myron Taylor Hall, Cornell University, Ithaca, N. Y., Monday and Tuesday, June 25 and 26, 1935, as a part of the summer convention activities. In attendance at these sessions were delegates from 55 Institute Sections and counselor-delegates from 8 of the 9 Districts in which committees on student activities have been organized. In addition to these officially constituted delegates, there were other officers, officers-elect, and Institute members in attendance, bringing the total recorded attendance up to 95. The principal topics under discussion at the conference were essentially as outlined in a program previously mailed to the delegates and others:

Monday, June 24, 11:30 a.m.

1. Opening of conference; announcements by I. Melville Stein, chairman of the Sections committee.
2. Remarks by H. H. Henline, national secretary.
3. Institute finances—L. W. W. Morrow for chairman of finance committee.

Monday, June 24, 2:00 p.m.

Session A—Sections Committee Meeting—I. Melville Stein, Chairman, Presiding.

4. Communication from membership committee—Everett S. Lee, chairman, membership committee.
5. Relations with other professional bodies; L. W. W. Morrow, chairman, committee on coordination of Institute activities.
6. Publications policy of A.I.E.E.—C. O. Bickelhaupt, chairman of publication committee.
7. Section prizes—R. L. Frisby, chairman, Kansas City Section.

Session B—Student Branch Committee Meeting—Prof. L. A. Doggett, Chairman, presiding.

8. A general discussion of student activities of the Institute.

Tuesday, June 25, 2:00 p.m.

Session C—General.

9. Report on student Branch committee meeting of Monday afternoon, including recommendations for consideration at this time by the joint group.
10. The coming year—President-Elect E. B. Meyer.
11. Résumé of Sections committee meeting discussions of Monday afternoon.
12. Student relations; co-operation between Sections and Branches—Prof. Ben S. Willis, chairman, Iowa Section.
13. Section technical committees—John Bankus, chairman-elect, Portland (Ore.) Section.
14. Improving Section activities—
    (a). Increasing value of A.I.E.E. membership—Prof. Ben. S. Willis, chairman, Iowa Section.
    (b). Relations with the Public—J. M. Todd, chairman, New Orleans Section.
    (c). Section territory—I. Melville Stein, chairman of this committee.
15. New business.

The annual report of Section and Branch activities was published in full on pages 674–5 in the June 1935 issue of ELECTRICAL ENGINEERING, and therefore no pamphlet copies of the report were prepared for use at the conference and nothing further remains to be reported here.

Opening Session

In his opening remarks, Chairman I. M. Stein paid tribute to the effective work of the program committee which, widely representative, was composed of Chairman W. H. LaMond of the Cleveland Section (chairman), Chairman J. M. Todd of the New Orleans Section, and Chairman A. M. Bohnert of the San Francisco Section.

Vice President R. B. Bonney, in speaking by request in the absence of President J. Allen Johnson, called attention particularly to the progress that is being made throughout the United States in the continued development of Sections and student Branches, stating that "the report indicates that the number of these organizations has increased steadily during the past few years." He stressed the important opportunities for Institute service offered to these annual conferences which bring together delegates from widely separated points, and urged that "the importance of the local meetings of the Sections and the Branches . . . should never be lost sight of."

Upon the request of Chairman Stein, Vice President W. H. Timbie of Cambridge, Mass., spoke briefly with respect to the social and economic aspects of engineering. Professor Timbie characterized the engineer as "the most liberally educated man in the world at the present time," saying further that, to his mind, "engineering is more than technological work," and that "the biggest mass of information in this country is possessed by the scientists and engineers." He said further: "The thing that we think we can well do is to bring out and discuss some of the social and technological implications of engineering and not leave it to the other fellow who does a different kind of thinking." He called particular attention to the "Report of Institute Committee on Sponsoring Discussions of Social and Economic Subjects" that was published on pages 672–3 of ELECTRICAL ENGINEERING for June 1935.

REPORTS OF NATIONAL SECRETARY AND FINANCE COMMITTEE

National Secretary Henline commented upon the opportunities for improvement of Institute activities that were offered through the widespread personal contacts made available through these annual conferences. Concerning Institute activities, Secretary Henline had the following comments to offer:

"During the past fiscal year which closed April 30, 1935, the Sections held more meetings than had been reported in any previous years . . . 521 meetings, with an average of about $8^1/_2$ meetings per Section . . . every Section has been active.

"The Branches also showed good records. During the past year 4 new Branches were organized, bringing the total to 117. About 50 per cent of the Enrolled Students who are coming to the end of their enrollment as students in the Institute are applying for admission as Associates, . . . nearly 50 per cent of the new members coming in.

"The Sections and Branches have continued the practice of holding a great many joint meetings, and as I have watched these meetings develop for several years it seems to me they are doing wonderful work in bringing the younger men into contact with the Sections. In many cases Branch chairmen become active in the Sections. Hence this joint work is bringing younger men into Section activities early after graduation.

"During the past year several new plans have been tried in the way of extending the Section activities and opportunities to greater numbers of their members. . . . Many Sections are doing excellent work in this respect. Some are holding special technical meetings between the regular meetings. The New York Section has operated 4 technical groups with great success. . . . San Francisco has been placing special technical meetings between the regular meetings, and Portland has also been successful in a similar development."

In speaking briefly concerning the question that has come up during the past year among some Sections concerning the question of co-operation with other groups, Secretary Henline mentioned the recent extension of American Engineering Council activities to provide for more simple and effective co-operation on the part of local groups throughout the country, and mentioned also the rapidly developing work of the Engineers' Council for Professional Development, pointing out that these and other similar opportunities for broader activities were readily available subject to the initiative and interest of the several local Section groups.

In reporting briefly for R. H. Tapscott, chairman of the finance committee, L. W. W. Morrow, member of that committee, referred to the board of directors report published in the July issue of ELECTRICAL ENGINEERING, pages 735–47, in which the complete financial statement for the fiscal year ending April 30, 1935, was published. In summing up briefly, Mr. Morrow pointed out that, with respect to the budget adopted in October 1934, the estimated receipts for the appropriation year ending September 30 were $218,000, whereas in the approximate 9 months' period ending June 21, some 86 per cent of the estimated 12 months' receipts had come in. Pointing out the further favorable balance, Mr. Morrow mentioned that the total expenditures for the 9 months' period were 73 per cent of the budgeted 12 months' amount. He reported with particular emphasis that the estimate on past dues paid in by those members that were delinquent already had been exceeded by a good margin.

To consider the question of the allocation of unexpended balances of Section appropriations, referred by the board of directors to the Sections committee for recommendations, Chairman Stein appointed a committee consisting of Chairman F. A. Hamilton of the Schenectady Section, Chairman-Elect John Bankus of the Portland Section, to serve with Chairman W. H. LaMond of the Cleveland Section. This committee was instructed also to consider resolutions that would more rigidly and equitably delimit the purposes for which the expenditure of Section appropriations would be permitted.

Sections Session

The first order of business in the Sections session Monday afternoon, June 24, was the report and discussion of the work of the membership committee.

Membership Committee Report

Everett S. Lee, Schenectady, chairman of the membership committee, spoke words of praise and high commendation to the many Section members and officers who have co-operated so effectively with the national membership committee during the past year: "I don't know how to express to you appreciation for the work that your Section membership committees have put into this job of membership this year. The reward of work well done is always more work; so your job is extended another year. Take that message back home to your Sections and see that your Section committees and chairmen are lined up in the coming year as they were in the past year."

For statistics, Chairman Lee referred to the tables included in the report of the membership committee as covered in the report of the board of directors (pages 740–1 Electrical Engineering July 1935) saying further:

"As to membership, as we see it, there are 3 groups—the Section membership committees, the membership of the Institute, and all those outside the Institute. We have tried to get the membership of the Institute to bring to the attention of the Section membership committees, and to those outside the Institute, the names of individuals that they thought should come in. . . . the figures speak for themselves.

" . . . Institute headquarters has done an outstanding job in tabulating all the names, particularly those 4,200 names of members who for the past 3 years have had various vicissitudes and problems and troubles—each man having almost a different story—keeping all those stories intact so that resolutions could be brought to the board of directors for the best action possible. . . .

"We worked all year this past year; there was no summer let-down on the part of the membership committees. This was productive of very good results, and we obtained several hundred applications during the summer. Be sure you work out the invitations to your summer activities so that your members will invite their friends. That works out very well. Membership committees are going on along this summer also, so the membership committee job has become a 12 months' job."

Chairman Lee commented extensively upon the tabular information of the published report urging study and comparative analysis of the information given there; pointing out the obvious results of diligent membership work during the past year or so, he said further:

"I think it all represents a better situation in the Institute. . . . I know that the Section membership committees certainly have a right to feel proud of their record. From every Section applications have been received showing the universality of our work. . . . a little healthy competition often helps. For instance, following a letter received from Chicago saying that Urbana and New Mexico were in the same category, with the same number of members, both these Sections obtained new members."

Subsequent discussion emphasized the fact that, in general, quality was to be preferred in preference to quantity, but that there was also plenty of potential opportunity for membership promotion in that now only 14,000 or 15,000 of the 57,000 considered to be potentially qualified for membership actually are enrolled. An extensive discussion of the subject of "local members" brought out the generally expressed belief that on the basis of experience, promotion of the local membership idea in Section territory might be satisfactory provided it was handled in such a way as to serve definitely as a channel to national membership and not as an alternative.

Relations With Other Professional Bodies

Director L. W. W. Morrow, chairman, committee on co-ordination of Institute activities, spoke extensively on the subject of Institute relationships with other professional organizations. He first outlined briefly the activities of the 8 joint functional organizations of which the Institute is a co-sponsor, and concerning which rather complete information was published in the July 1935 issue of Electrical Engineering, pages 788–94. Mr. Morrow continued:

"Then we come to 2 distinctly new movements."

Engineering Registration

"One is the development of a movement, through law and other restrictive measures, to make engineering a guild or a very exclusive professional organization which, through licensing and through membership restrictions, is largely limited to a man who has had technical training and who is in actual technical activities as a specialized professional technical man. That movement has been developing rapidly. There are licensing laws now in most of the states, and the qualifications are largely technical.

"The guild movement, as I call it, if we followed it to its logical conclusion, would mean that no one could be a member of any of these engineering societies who could not be a licensed engineer in specialized professional technical work. It relates in a sense to law and medicine in its motivation, without reference to the fact that a lawyer or a doctor is rendering a personal service to an individual client, while engineering is a functional service entirely distinct from the other professions. But this movement is going on, and certain national professional engineering associations are being developed with the intention of making engineering a specialized profession, limited to technical men and excluding all that vast group of functional men that we call engineers who are not engaged in purely technical work.

"That movement, so far as the Institute is concerned, is represented by certain organized groups. One of them is the National Council of State Boards of Engineering Examiners. Another is the new society —the National Society of Professional Engineers. In a sense, the Engineers' Council for Professional Development also ties into that group. Through its 4 committees on student selection and guidance, professional training, engineering schools, and professional recognition, E.C.P.D. now is tending toward a sane development of that approach, not only in the selection of the students and the grading of the colleges, but in the post-graduate training and career work following graduation. The procedure is based largely upon the conception of engineering as being a guild or essentialy technical. The E.C.P.D. has been busy for 2 or 3 years laying the foundation for this work. It represents the several engineering societies and the National Council of State Boards of Engineering Examiners. Certain movements have been approved, such as the grading of engineering colleges. The committee on student selection and guidance is rapidly developing valuable material, and we are on the horizon of giving a new definition to engineers which we would rate as a requirement for membership in the Institute.

"That development requires study and I think should be discussed in front of all Sections this year. There are 2 points of view in these new developments. One is the exclusive point of view, and the other considers the function of engineering in modern life today that takes in the extremes from the business man to the narrow specialist. . . .

"We should be slow in taking action on these matters. The Institute is co-operating and is trying to take a sane viewpoint; it is not antagonistic. The problem is here and must be met. . . . "

Social and Economic Questions

"The second movement is distinct. . . . With the new developments in this country, engineers as well as everybody else are concerned with and interested in the social and economic aspects of national affairs. They think engineers should participate.

"Up to this time the only function of the Institute along that line was co-operation with American Engineering Council, which has functioned in Washington largely as the 'Embassy' of engineers. . . . But the pressure and the whole scene have changed so greatly that one of the late movements is for the American Engineering Council to decentralize and have in each state a committee of the same general type, that . . . could act with respect to legislation and social and economic matters in the state. That is being instituted as a broad-gauge movement, so that engineers are represented in the legislative councils, in state action, and in the social and economic scene where their opinions and advice will count. . . .

"The board (of the A.I.E.E.) itself has taken action recently (see page 672, Electrical Engineering, June 1935) to make possible in the Institute a broader policy regarding papers on social and economic affairs. Because this time is as it is, these things are more acute than they may be a few years from now, and now is the time for such discussions. But meetings on these subjects should be planned intelligently. . . . These subjects must be handled with more care than talking about a new design of a machine, for instance.

"Thus, this broad movement to participate more actively in national affairs—social and economic—is manifesting itself: (1) in relation to other societies, largely

through the development of the American Engineering Council; (2) indirectly . . . in the E.C.P.D. procedure; and (3) in the Institute in this new broad action of the board and in the programs contemplated for this year.

"How far to go in that direction or in the other extreme specialization direction should be discussed fully. It is a serious matter, and decisions should be based on information from the ground up."

A.I.E.E. Publication Policy

C. O. Bickelhaupt, New York, chairman of A.I.E.E. publication committee, presented a comprehensive digest covering recent developments in the policies and procedures governing the Institute's publications. In presenting his report, Mr. Bickelhaupt stated that the present procedure was subject to further development and urgently requested that the committee be given the benefit of any comments and suggestions that would reflect membership desires in connection with the publication services. (Mr. Bickelhaupt's report is scheduled for publication in full in the September issue of Electrical Engineering.)

In closing his comments, Mr. Bickelhaupt pointed out "that in carrying on the publication work in these very difficult and trying times it is very gratifying to know that we have been consistently reducing our expenditures and at the same time doing what we consider to be a creditable publication job. . . . Section delegates are entitled to know that the publication's expense for the current year is about 40 per cent less than it was for 1930. . . . "

Counselor-Delegates Session

According to the report presented by Prof. L. A. Doggett, of Pennsylvania State College, chairman of both the committee on Student Branches and committee on education, the afternoon's deliberation of the counselor-delegates and other persons interested in that phase of the work was given over to:

1. Consideration of the annual Sections and Branches report as published in the June 1935 issue of Electrical Engineering.
2. The question of national prizes for student papers.
3. The question of eligibility for student Branches of certain schools which have not been given that privilege.

Out of an afternoon's discussion, 2 resolutions were forthcoming:

1. Resolved that the committee on student Branches requests that the board of directors give consideration to re-establishing the office of assistant national secretary to give his time to student activities.
2. Resolved that articles written definitely to interest the students be regularly published in Electrical Engineering under the sponsorship of the Institute's committee on education.

Closing General Session

The first order of business of the reconvened general session was the presentation of the foregoing resolutions by Prof. L. A. Doggett, who, in discussing them, stated "We have felt that the student Branch activities have not had in the last several years sufficient support from the Institute at large. . . . As one matter of evidence, we have noted with considerable worry the fact that the attendance at the student Branch meetings has fallen off in the last 3 years from a peak of more than 60,000 to a low point last year of 36,000, whereas the attendance at Section meetings held practically constant at about 73,000. That change seems to be coincident with the new publication policy, which has totally removed the word "student" from Electrical Engineering. Therefore, we have 2 requests in the form of resolutions which we wish to pass along for the consideration of the board of directors."

Both resolutions were adopted after brief discussion and without dissenting vote.

President-Elect Meyer Speaks

Responding to Chairman Stein's request, President-Elect Meyer spoke briefly.

A message from Mr. Meyer is given on page 807 of this issue; another is scheduled for publication on the first text page of the September issue.

Section Activities

Prof. B. S. Willis, chairman, Iowa Section, speaking on assigned topic "Student Relations; Co-operation Between Sections and Branches," emphasized the importance of student Branch work by " . . . a student Branch is the field in which any missionary work is sure to bring lasting returns. We should strive to interest every student in electrical engineering in the Institute through the student Branch and to sustain his interest to such a point that he will when eligible transfer to the grade of Associate. We all give our moral support to the student Branches, and the Institute has wisely provided reduced dues and financial assistance to the student Branches, and prizes and other concrete tokens of encouragement. But I think the Sections in many if not in most cases do nothing active in the way of stimulating the interest of the students and encouraging the student Branches—that is, nothing definite."

Mr. Willis urged the individual member to "go out of his way to show a friendly interest in every student in electrical engineering with whom he comes in contact," and urged Sections to "prepare and circulate to the student Branches in nearby territory a list of young and enthusiastic speakers available for student Branch meetings." Discussion on this subject led to the adoption of the following resolution:

Resolved that it is the sense of this group that the Sections interest themselves more in student activities.

Further discussion on the same general topic led into the field of prizes and other means of tangible recognition and encouragement for student papers. Some urged more "assistance" of various tangible forms on the part of Sections and on the part of the national organization. However, the general consensus of opinion in accord with established facts was expressed by Vice President F. O. McMillan of Corvallis, Ore., who was a Branch counselor for a considerable number of years.

"I believe this discussion indicates clearly that the real fault in the situation lies with the counselor. The counselors are the persons responsible for the activities of these student Branches, and not the Sections. The Sections, of course, must co-operate with the Branches, and the Branches need their co-operation, but after all, the counselors must assume the responsibility for the activities of their own particular Branches. It seems to me that the whole difficulty lies in the fact that our student Branch counselors have not been sufficiently interested in or active enough to see that student papers are submitted" (so that they may receive consideration for District or national prizes).

Section Technical Committees

John Bankus, chairman of the Portland Section, spoke at some length on the assigned topic of Section technical committees as organized and successfuly operated by his Section. The full text of Mr. Bankus' report, together with supporting figures revealing the Section's experience, is scheduled for publication in the news section of the September issue of Electrical Engineering.

A brief résumé of some of the principal topics presented during the discussion on "Improving Institute Activities" is given in the following paragraphs:

Chairman Ben S. Willis of the Iowa Section suggested giving "every member of the Section a job in the work of the Section," and providing a "balanced program" including other than purely technical material and formal activities, as a practical means of increasing the interest and participation of individual Section members. With particular respect to Sections removed from the few really large centers of population of the country, he recommended also "that the national officers visit Sections more than they do . . . each Section should receive at least one visit per year from at least one national officer." He mentioned also the desirability of developing an increasing loyalty to and faith in the Institute.

J. W. Bennett, chairman of the Springfield (Mass.) Section, urged the desirability of developing speakers for Section meetings from among the Section membership, and emphasized the desirability of diversified meeting programs.

L. B. Robinson, Seattle, described the success of the Seattle Section in having student members present short talks in advance of the main address for Section meetings. He said "in general we will have 1 or 2 or 3 of the young men participate, in some cases giving a little historical sketch as a background for the main paper . . . in other cases giving some of the fundamentals on which the main paper may be based."

Concerning the relationship between the engineer and the public, Chairman L. H. Burnham of the Pittsfield, Mass., Section, described the Pittsfield Section as "an established institution in the life of the city of Pittsfield, recognized as such by the residents of the city." He pointed out that Pittsfield is far removed from large cities, and that the local Section of the Institute has, somewhat as a function of a civic organization, developed a large local supporting nontechnical membership for whom the Section holds a series of popular lectures on scientific and other topics during each season.

Section Territories

Chairman Stein reported briefly on the present status of the work of the special committee (E. B. Meyer, L. W. W. Morrow, E. S. Lee, I. M. Stein) appointed by the board of directors to study the proposition of revising Section boundary lines to include all parts of the United States in Section territories. He reported that the work was under way and would be reported upon at a later date.

Section Expenditures

Receiving the report of the special committee (W. H. LaMond of Cleveland, F. A. Hamilton of Schenectady, and John Bankus of Portland) appointed at the opening session of the conference for the purpose of drawing up a resolution that would convey to the board of directors the sense of opinion and recommendations of the conference concerning questions pertaining to Section appropriations, Chairman Stein presented the report to the body for consideration:

"Appreciating fully what the finance committee has done and is doing to keep expenditures within income, your committee recommends:

"1. That any Section holding at least 6 technical meetings per year shall not be obliged to return any expended balance of funds in its treasury.

"2. That traveling expenses in connection with District and national meetings shall be considered as outside of local Section activities and therefore should not be incurred by a Section.

"3. Inasmuch as '2' directly above will tend to limit attendance of delegates to District and national meetings, we urge restoration at the earliest possible date of traveling expenses to the former level of 10 cents per mile one way.

"4. That expenses for social meetings shall not exceed 15 per cent of total expenses for the year."

After rather extensive discussion as to whether or not it was advisable to recommend permissive action whereby local Sections could spend for convention delegates' traveling expenses any portion of the fund allotted to the local Sections for carrying on their local activities, the committee's report and recommendations were turned into a resolution and adopted as follows:

Resolved

1. That any Section holding at least 6 technical meetings per year shall not be obliged to return any unexpended balance of funds in its treasury.
2. That we urge restoration, at the earliest possible date, traveling expenses to the former level of 10 cents per mile one way.

Thus, this became the conference's recommendation to the board of directors in response to the questions referred to the Sections committee by the board for an expression of opinion.

Recognition of Section Competitions

Concerning the question of "national recognition of Section competitions to the extent of offering some sort of a prize," a special committee appointed the previous day by Chairman Stein (C. D. Brown, Milwaukee, R. L. Frisby, Kansas City, F. A. Hamilton, Schenectady) presented for discussion and consideration, the following resolution:

Resolved, that acceptable competitions conducted by the Sections, particularly for their younger members, result in many benefits to the Sections and to the Institute as a whole, these benefits comprising among others (1) increased membership, (2) increased participation in Section and Institute affairs, and (3) increased opportunity for self-development; and believing that Sections not now conducting competitions would be encouraged to do so by some form of national recognition, it is recommended to the board of directors:

1. That a certificate or other token, as may be decided from time to time, be made available each year to each Section holding during that year an acceptable competition, such awards to provide suitable recognition of the winner of the competition.
2. That any competitions, conducted according to rules adopted by Section executive committees, that are approved by the Sections committee and the committee on prize awards, shall be eligible for this recognition.
3. That national recognition of Section competitions, as outlined above, be given at the earliest possible date consistent with Institute policy.

Without discussion, this resolution was adopted unanimously and ordered referred to the board of directors for consideration.

With a unanimous "vote of appreciation. . . for the above conduct of this conference," the conference adjourned to reassemble in Los Angeles in 1936.

Reports on 14 Technical Conferences Held During the Summer Convention at Ithaca

An innovation introduced during the recent A.I.E.E. summer convention at Ithaca, N. Y., June 24–28, 1935, was the holding of a series of informal or round table conferences on technical and educational problems of the electrical engineering profession. These conferences were scheduled primarily for the benefit of specialists and the younger members, and were, in general, sponsored by subcommittees of technical committees. They afforded an opportunity for an interchange of ideas, regardless of whether or not the individuals interested were members of technical committees.

These informal technical conferences were held during the afternoons of the week of the convention, so as not to interfere with the regular technical sessions in which the formal papers were presented during the mornings. They proved even more successful than some sponsors had expected, and were attended by a large number of those present at the summer convention, in spite of the fact that as many as 5 were held in parallel.

In all, 14 of these conferences were held. Brief news accounts covering each of the conferences follow.

Transformers

By J. E. Clem, Chairman

The following report of the conference on transformers is intended as an informal news report, and not as a record of the technical opinions presented.

There were about 50 people present at the conference on transformers which mainly was in reference to the new standard bushings for distribution transformers, instrument transformers co-ordination, and the impulse test code.

A report on plans to formulate specifications for a standard line of bushings for distribution transformers was presented. During the discussion it was brought out that some time ago the transformer subcommittee agreed that the standard impulse flashover for bushings should be approximately 5 per cent in excess of the impulse flashover of the test gap used in testing transformers. Bushings for power transformers had been practically standardized as to flashover for sometime and the flashovers corresponded to the standard for the higher circuit voltages but exceeded the standard for the rated circuit voltages at the lower end of the voltage range. Inasmuch as this practice had resulted from experience, it was decided not to attempt to reduce the flashover of power transformer bushings down to the standard flashover values adopted.

The situation was different for distribution transformers and it was necessary to agree upon a line of flashovers in agreement with the standard together with the corresponding wet and dry 60 cycle flashover voltages. The discussion mainly was in reference to the fact that the flashover voltage for distribution transformer bushings was different and lower than that for power transformer bushings. There was some sentiment in favor of using but one standard flashover level for both power and distribution transformers. It was pointed out that the service record of distribution transformers has been, in general, quite good, and that transformers designed to withstand the tests according to the impulse test code with the proposed line of bushings would, in general, be stronger in insulation strength than the design of a few years ago. It was also pointed out that increasing the insulation strength of distribution transformers to the level required by the power transformer bushings would result in increased costs to the industry that are very difficult of justification.

The co-ordination of instrument transformers was extensively discussed. It was brought out that a situation exists, in regard to instrument transformers, which is similar to that for distribution transformer bushings. As a result of many years' experience, instrument transformers of 2 insulation levels are available. The higher level corresponds, in general, to that of distribution transformers of the same apparatus voltage classification and the lower level corresponds approximately to the next lower circuit voltage level. Many of those present could see no need for 2 insulation levels, but it was pointed out that about 80 per cent of the sales had been for equipment in the lower insulation level. Interchangeability of equipment was thought to be the major factor toward retention of the double standard. It was felt that ultimately there would probably be but the one insulation level and that the change-over would be more or less a gradual process.

The impulse test code has been in use for some time now and proposed modifications were discussed. There is a growing tendency toward requiring that impulse tests be made on the basis of kilovolts with a specified wave rather than on the basis of a given length of a rod gap. It was pointed out that the rod gap was chosen as the basis of impulse test at the time the test code was formulated because the various laboratories did not report the same kilovolts as the flashover of the gap. This difficulty has been fairly cleared up now and it seems desirable to change over to a kilovolt basis when the test code is revised.

Several proposals have arisen lately to modify the impulse test procedure. F. J. Vogel advocated a definite relation between the impulse test value and the low frequency high potential test in the factory. Some of the operators felt that the present impulse test does not take into account the fact that very steep voltage waves may be impressed on transformers in service. Present knowledge indicates that the lightning voltages to which transmission lines and connected apparatus are subjected bear a definite relation to the flashover value of the line insulation or to the voltage value permitted by protective apparatus, and that it seems reasonable to assume that the rate of voltage rise which lightning imposes on transmission lines expressed in kilovolts per microsecond bears no relation to the circuit voltage. It must be recognized that the lower voltage circuits will undoubtedly be subjected to considerably higher voltage in relation to circuit voltage than higher voltage circuits. These circuits are usually on wood pole lines and the flashover value of part of the wood is usually added to that of the insulator. Induced voltages on low voltage circuits may reach flashover value of the line or apparatus insulation. In general, this means that the lower voltage apparatus will receive a proportionately greater number of waves of dangerous magnitude and the rate of voltage rise in proportion to apparatus rating is increased.

F. F. Brand then suggested that lightning impulse tests, irrespective of the circuit voltage, be made at a definite rate of voltage rise and the value of voltage to be applied to the transformer be established in consideration of the limits to which protective apparatus hold this voltage. It was generally recognized that such a method of impulse testing was desirable and there was much discussion as to possible methods of making such tests. It was suggested that there might be difficulty of measuring very short times to flashover but it was pointed out that this difficulty might not be serious because when the time is short the voltage is low.

Research on Insulating Oils

By K. S. Wyatt, Chairman

The conference on research on insulating oils was highly successful, for not only was the attendance excellent, some 70 people being in attendance, but the discussion was active and of a stimulating and helpful nature. Most significant was the fact that several groups were represented who have worked on the oil problem in comparative isolation one from the other, namely, electrical engineers from the utilities, chemists both organic and physical from the oil refineries, and researchers from the universities.

Although the main object of the conference was to discuss ways and means of improving the stability of insulating oils, some attention was first directed at the economic importance of the oil problem to the electrical industry. Herman Halperin presented figures to show that the utilities in this country had an investment of $2^1/_2$ billion dollars in oil-insulated electrical equipment, which was being added to at the rate of 100 million dollars per year. Although the normal annual expenditure for insulating oils is small, about 3 million dollars, it was agreed that the problem of oil stability was of great enough economic importance to the industry to make imperative a strong research investigation.

The nature of deterioration of oils in service received some attention. C. F. Hill pointed out that the chief cause is oxidation, with contamination by gum, acids from varnish, and contact with metals as secondary factors. He emphasized that the degree of refinement had a marked influence on stability. Breakdown is thought to be largely a function of moisture content, an oxidized oil having higher dielectric strength if well dried. Viscosity and surface tension influence breakdown in service. Dr. J. B. Whitehead stated that the problem of deterioration of insulating oils is the outstanding problem in the advance of the art of high voltage underground power transmission. Two experimental methods might be followed, one large scale, simulating conditions in the factory, and the other the basic study of the inherent properties of oil. For the latter he suggested that measurements of conductivity, dielectric loss, dielectric strength, specific inductive capacity, and viscosity together with chemical tests should be made on different types of oils during subjection to high electrical stress and temperature under controlled oxidizing conditions. The influence of moisture must also be studied. Dr. Kenneth Hickman stressed the importance of the paper in accelerating oxidation of the oil, stating that peroxides are formed when paper is subjected to light or ozone and perhaps these or the rosin in the paper cause trouble. Professor Lars Onsager said the electron was the only active agent in the breakdown of oils. O. E. Fawcett described a detailed research program on transformer oils; he intends to investigate the possibility of adding some material to the oil to prevent oxidation.

The main discussion of the conference centered around ways and means of improving oils. D. W. Roper stated a new situation had developed in that some oil companies had introduced solvent refining methods which seemed destined to replace old-time acid refining processes. The new methods make it possible to select certain groups of hydrocarbons from the crude, some which it is highly probably have superior stability for electrical purposes if properly refined. He emphasized the effect of natural impurities and of contaminants on electrical stability. He listed the requirements for good cable oils and for good transformer oils. He was followed by E. H. Hillman, who thought that the best method of selecting samples for research was to obtain standard brands of motor oils now on the market. He championed the acid refining process. A. P. Anderson, on the other hand, thought the best method was to separate the constituents of each of 3 crudes covering the whole range of paraffinicity into 5 fractions, and to test each of the 15 samples for stability by all chemical and electrical measurements available during an aging program simulating service conditions. He thought that in improving these oils, the influence of chemical composition is of primary importance. The objection to working with motor oils now on the market is that there is no assurance that the hundred details of handling which may affect electrical properties will remain constant.

A short discussion then took place on the importance of developing more precise micro-methods for measuring the characteristics of oils. Dr. W. F. Davidson thought the development of such methods essential before progress could be made. He described several new methods; the determination of peroxides and copper soaps in oil; the potentiometric titration of acids in oils; the hydrophil method for the determination of oxidation products, and new micro-power-factor cells. Prof. J. C. Balsbaugh described a Shering bridge and vacuum cells for measuring power factor of small oil samples over a range of frequency. In the low range, power factor is affected by electrode material. Dr. Harvey Curtis preferred d-c measurements to loss measurements, thinking they would tell the whole story more cheaply and simply. He also said the more different were the types of attack on the oil problem the more rapidly would the solution come.

The results of the conference already have been of value for on the ideas suggested there the Edison Research Co-ordinating Council (sponsored by the Association of Edison Illuminating Companies) is basing its broad program of research on insulating oils to be started at the universities this fall. It is hoped that further conferences of a similar nature, but covering a narrower field, will be held under A.I.E.E. auspices.

Problems of the Student and Cadet Engineer

By M. G. Malti, Chairman

The conference of problems of the student and cadet engineer was opened with remarks by Prof. L. A. Doggett, chairman of the committee on education. He was followed by H. S. Osborne, who spoke on "The Future of Engineering and the Young Engineer." Dr. Osborne emphasized the fact that as long as science progresses there is bound to be a demand for engineers. He asserted that the present depression is only a temporary thing, and that the unemployment among engineers is bound to disappear with the depression and that the future will see an ever increasing demand for engineering service.

Dr. Osborne's talk aroused a great deal of interest and led to considerable discussion. The majority of those present agreed with him. The chairman of the conference stated, in support of Dr. Osborne's thesis, that scientific progress always leads to increased employment, and to a greater demand of engineering service. He pointed out as an illustration the radio industry, which sprang up like a mushroom, demanding not only technical services but also

ordinary labor. He further asserted that it is not scientific advance which causes unemployment, but rather ordinary inventions whose object it is to displace labor.

Among the speakers who discussed Dr. Osborne's paper was L. V. Reese, whose remarks were extremely timely and very beneficial, especially to the young men present at the conference. He gave those men some very practical and helpful suggestions, covering the most effective method of finding employment.

This period of discussion was followed by a talk by Alan Howard, who discussed "The Young Engineer in Industry." Mr. Howard emphasized the fact that the young engineer needs ability to sell his services as well as the capability of solving engineering problems. These 2 requisites, Mr. Howard pointed out, should go hand in hand, for if an engineer cannot do engineering work he has nothing to sell, and if he cannot sell his engineering services he will be unable to find employment.

He was followed by Prof. W. H. Timbie, who, speaking of the value of an engineering education in a non-technical and semi-technical career, emphasized the fact that and engineering education is beneficial not so much because of the facts that it gives to the engineering student, but rather because of the type of mental thinking it develops in him. He stated that the engineer is taught that his profession is one of service rather than of money-making, and that the engineer finds his highest satisfaction in serving humanity.

R. E. Hellmund, in discussing "The Qualifications of a Successful Engineer," stated that it is essential for engineers to maintain a balance between opposing qualifications in order to be successful. He took as an illustration 2 qualities, "ability, and industry," and stated that a person could be 100 per cent industrious, but zero per cent capable, and not accomplish anything. On the other hand, he could be 100 per cent capable but not industrious at all, and again not accomplish anything. Accomplishment, Mr. Hellmund stated, depended upon maintaining a balance between these 2 traits. These 3 talks provoked considerable discussion, after which Prof. C. L. Dawes spoke on "The New Graduate School of Engineering" and A. C. Stevens discussed the Engineers' Council for Professional Development.

Attendance at this meeting was well over the 100 mark, and it is gratifying to state that many of those present expressed their satisfaction at the discussion, as well as the papers presented. There is unquestionably a place for such technical conferences in the A.I.E.E. conventions, and it is hoped that this experiment will be continued in the future.

Mercury Arc Rectifiers

By O. K. Marti, Chairman

The attendance at the conference on mercury arc rectifiers was about 40 people. The first subject discussed was water cooling of rectifiers, corrosion, and remedies for the latter. It was pointed out that in order to carry off the heat losses from a rectifier, water is used for large iron-tank units. It was recently found that in some places, due to chemicals in the water, corrosive action is quite pronounced if tap-water cooling is used. Therefore, several other cooling schemes have been proposed, and most of the rectifier installations are now equipped with recirculating cooling systems on this account. R. O. Nixon submitted some data collected on the system of the Philadelphia Rapid Transit Company, which show that corrosion cannot be fully taken care of by the use of a film of paint applied to the water jacket and vacuum tank. Improvement in the amount of corrosion was, however, pronounced with certain paints, but the difficulty lies in that the paint, after a certain length of time, and especially if higher temperatures are used for the cooling water, scales off. Furthermore, his report showed that a considerable improvement was obtained by adding a corrosion-inhibiting chemical to the cooling water in the recirculating current. Mr. Nixon showed several slides illustrating the deposits of sludges resulting even from the use of drinking water and he brought out the fact that considerable pitting due to corrosion was found under the sludge, with their particular method of cooling.

O. K. Marti brought out the fact that by the use of the latest cooling system—i. e., recirculating cooling—introducing a heat exchanger, and insulating the latter from ground, practically no corrosion has so far been observed in many installations throughout the country, over a period of many years. He pointed out that it is, however, necessary that no air be added to the cooling water system, and that this provision can be met by using an expansion tank of the proper design. In this way not only is the corrosion due to aeration eliminated, but (through the insulation of the whole cooling system) the leakage current to ground is considerably reduced. J. J. Linebaugh stated that the use of the corrosion inhibitor in installations at voltages as high as 3,000 volts gave excellent results in such cooling systems as discussed above. Other preventive means were discussed, but it was felt that the use of a recooling system, insulated from ground should overcome these difficulties mentioned by Mr. Nixon. If this should not be sufficient, then the inhibitor could still be used in such a recooling system, and Mr. Nixon's data showed that it was effective in their system, which, however, permitted aeration.

R. L. Jenner showed a new development of a porcelain cooling coil, which can be used instead of rubber hose, especially in high voltage rectifier plants.

Another subject discussed was interference with communication circuits due to harmonics produced in the a-c supply circuits of mercury arc rectifiers. Dr. J. J. Smith outlined briefly the reason for possible interference caused on the a-c side of rectifier installations. P. W. Blye elaborated on this matter, and showed the relation between the power systems and the telephone systems, and developed the theory of some filter equipment which could be applied to the primary a-c network. H. E. Kent stated the various means for minimizing this interference on the telephone side as well as on the power side.

A third subject discussed was the proposed A.I.E.E. Standards, particularly regarding dielectric tests. On this subject, J. H. Cox and G. R. McDonald contributed a great many data, from which the conclusion was reached that it is immaterial whether dielectric tests are made under vacuum or at atmospheric pressure. Mr. McDonald discussed at length a tabulation of dielectric test specifications according to the rectifier standards of 3 different countries. It was also suggested that the A.I.E.E. Standards should be limited to voltages used in connection with present railway systems, say, 3,000 volts direct current, and that an addition to the present proposed Standards be prepared for rectifiers used in connection with higher voltages than 3,000 volts direct current.

D-C Test Code

By R. W. Owens, Chairman

At the conference on the d-c test code there were 14 people present, all of whom took an active part in the discussion.

T. T. Hambleton spoke of the determination of running light losses which are used in measuring the efficiency of d-c machines. L. R. Sellers discussed the various methods of setting the brushes on neutral with the advantages and disadvantages of each method.

The problem of maintaining a high insulation resistance in the field, together with the value of such measurements was the topic of C. H. Sanderson. Prof. W. I. Slichter who has given many years to the study and experimentation of determining a satisfactory means of measuring stray load losses gave a thorough talk on this subject. Mr. Hambleton also discussed the limitations in describing commutation.

T. M. Linville had just completed a study of the problems of flicker encountered with slow speed engine driven generators and gave his conclusions on this subject.

The meeting was open for subjects other than those scheduled and there were interesting discussions of many other problems which are involved in arriving at a standard of testing which would enable any manuacturer or user to make the same test report if testing an identical machine.

Circuit Breaker Standards

By R. T. Henry, Chairman

The technical conference on circuit breaker standards was attended by about 20 people. The principle feature of the discussion was a presentation by D. C. Prince of his experiences at the conference of experts on circuit breakers at Berlin, Germany, in April 1935. Mr. Prince described the discussions at that meeting regarding European and international standards for oil circuit breakers. R. E. Hellmund supplemented Mr. Prince's remarks and described his experiences at a similar meeting last year. J. E. Goodale presented some lantern slides illustrating the various methods of determining the current interrupted by circuit breakers.

A large part of the discussion covered the method of determining the current interrupted by circuit breakers and the question of whether this current should include only the a-c component or whether the a-c and d-c components should be included. Engineers in the United States and Great Britain favor including both the a-c and d-c components, while those in Germany and a num-

ber of the other European countries favor including only the a-c component. In this connection the oil circuit breaker committee of the Association of Edison Illuminating Companies has proposed a definition and specification of the current interrupted, and the discussion included this proposal.

There was also some discussion of the recovery voltage and the rate of rise of recovery voltage and the effect on the performance of oil circuit breakers.

A brief discussion of the situation regarding the test voltages for oil circuit breakers took place. There was also some discussion regarding the 1 second and 5 second current ratings for circuit breakers.

No definite action was taken on any of these subjects, but there was a rather free discussion and the conference served to present quite clearly the present status of some of these questions.

Reactance Coefficients of Synchronous Machines

By C. M. Laffoon, Chairman

The discussion on reactance and time constant coefficients of synchronous machines proved to be very interesting and profitable. Approximately 40 to 50 representatives were present from the manufacturing companies, technical schools, and operating companies.

There was a very lively and interesting discussion on the influence of saturation on reactance and time constant coefficients. Written discussions were sent in by Messrs. Early, Evans, Mortensen, Beckwith, Kilgore, and Laffoon. Oral discussions were concentrated on the application of reactance coefficients and the effect of saturation under different operating conditions. Oral discussions were given by Messrs. Peterson, Crary, Jones, Shirley, Mortensen, Kilbourne, and Kilgore, and by Professors Kingsley, Dennison, Bibber, Malti, and Lanier. There were also discussions by several other representatives whose names are not recalled.

From the discussions, the following general conclusions can be drawn:

1. The effects of saturation on reactance and time constant coefficients should be considered in applying these coefficients to most operating conditions.
2. The definitions and methods of test should be based upon values corresponding to rated current conditions, in order to minimize the expense and hazards involved in making the tests.
3. The values of reactance and time constant coefficients for other operating conditions should be obtained by multiplying the values at rated load condition by factors which can be taken from curves for the different types of machines.
4. Sufficient data are not available at the present time to reach a definite agreement in regard to the magnitude of the factors and the shape of the saturation factor curves for different classes of machines. This information is to be obtained from the different manufacturing companies by the subcommittee on synchronous machines.

Noise

By P. L. Alger, Chairman

At the conference on noise, and the meeting of the A.I.E.E. committee on sound which was held during the morning of the same day, it was considered desirable to proceed with the formation of a test code on noise measurements, recognizing that although in its early form it would be very sketchy, it will finally evolve into a very useful guide for practical work. The objective should be the adoption of generally understood and agreed upon methods of describing noise made by various types of electrical apparatus, these methods to be in accordance with the American Standards Association fundamental and meter standards already developed, and so far as possible consistent with methods to be developed by other groups such as the National Electrical Manufacturers Association.

The 4 major types of electrical apparatus to be considered in making such noise measurements are domestic appliances, office appliances, factory and substation equipment, and transportation equipment. The problem of describing noise of transportation equipment was deferred to a future time. The initial procedure to advance the work in the first 3 groups, however, falls into the following classes:

1. Draft of a general plan for describing apparatus noise under service conditions.
2. Draft of a general plan for describing apparatus noise under factory acceptance test conditions.
3. Preparation of an educational article on transmission of sound waves.
4. Collection of data on noise levels existing in home, office, etc.

Although it would be ideal if the apparatus noise could be determined under factory acceptance test conditions, and the acoustical properties of the environment could be determined by measurements in such a way that the noise under service conditions could be calculated from these 2 sets of data, it was agreed that in the present state of the art it is not practical to make such calculations, due to the complexity of environmental conditions. Therefore, the procedure in investigating noise conditions should be approximately as follows:

1. Measure the noise levels existing with the apparatus or noise source in operation.
2. Repeat the measurement with the apparatus shut down.
3. Determine the noise of the apparatus alone under factory acceptance test conditions.
4. By reverberation and other measurements, determine the degree to which the noise from the apparatus is affected by reflection, absorption, and other environmental conditions.

The ideas agreed upon as basic in preparing instructions for factory acceptance tests of noise were, broadly, as follows:

1. For convenience, a single point measurement of noise should be used wherever practical.
2. This noise measurement should be made in a direction corresponding to the maximum intensity noise produced.
3. The readings should be taken relatively close to the apparatus to minimize reflection effects of the environment, but far enough away to in some degree average the noise developed by the whole piece of equipment. Suggested standard distances are: 1 foot for very small apparatus; 3 feet for miscellaneous industrial equipment; and 50 feet for outdoor equipment or buildings.
4. When more than one marked frequency tone is produced, separate readings of the principal notes should be recorded.
5. Apparatus noise measurements should be made in an enclosure acoustically as dead as possible, or with minimum sound reflections.

It was also agreed that it is highly desirable to collect more authoritative information on the existing noise levels under all sorts of living conditions, determined with the American Standards Association standard on level meters. While much data has been published before on this subject, it has been in the old terms, with many discrepancies in the methods of measurements. Tables of data for noise surveys showing the levels estimated in accordance with the new A.S.A. standards, but measured with an unweighted meter, and also data on noise levels measured with a weighted meter and based upon the new A.S.A. standard reference level of 10^{-16} watts per square centimeter, were presented.

Dielectric Theories

By Hubert H. Race, Chairman

The conference on dielectric theories was attended by about 50 persons; it was entirely informal and is believed to have accomplished the purpose of providing opportunity for the exchange of ideas and information among those interested in this very specialized subject. The discussion was divided into 2 parts:

1. Dielectric properties of ice.
2. Dielectric properties of cellulose derivatives and fibrous insulation with special reference to the effects of water.

The underlying theories and considerable data on the first subject were presented by Dr. E. J. Murphy. General conclusion from the discussion of this subject was that the most probable theory for explaining the observed results is that of polar orientation.

The second subject was opened by Dr. J. B. Whitehead with a paper on the "Theories of Dielectric Capacitance and Loss in the System Cellulose-Water." The paper by Doctor Whitehead was followed by a presentation of electrical measurements on materials such as linen paper, kraft paper, "cellophane," and cellulose acetate by Dr. S. O. Morgan. The general conclusions from the discussion on the second subject were:

1. There are 2 dielectric polarizations in cellulose, one having a long relaxation time, probably due to electrolytic materials and very greatly depending on moisture content; and the second having a much shorter relaxation time, being dependent upon the cellulose itself and not very sensitive to moisture content.
2. In hygroscopic materials which have not been dried with extreme care, the dielectric losses at power frequencies probably result from conduction in adsorbed moisture films.
3. In very carefully dried materials, the observed dielectric capacitance and dielectric loss data appear to be best explained by the mechanism of polar orientation of hydroxyl (OH) groups.

Tensor Analysis

By A. Boyajian

The session on tensor analysis was sponsored by the electrophysics committee under Dr. W. F. Davidson, and the details of the program had been worked up by Prof. E. E. Dreese, chairman of the conference. On the program were 5 invited speakers, including engineers, physicists, and mathematicians, and the discussion of the significance and value of tensors in electrical engineering was participated in by a large number from the floor.

Anticipating the question which was bothering many minds, namely, "what is a tensor, anyway?" the chairman called on A. Boyajian to outline "The Nature of a Tensor." He presented the tensor to the audience as nothing but a "generalized vector," and proceeded to generalize the vector concept in easily understood terms

One of the informal technical conferences which aroused considerable interest and discussion was that on tensor analysis. Here is Gabriel Kron (center), exponent of the use of tensors, explaining a tensor analysis relationship to Dr. Ernst Weber (left) of Brooklyn Polytechnic Institute, and to Prof. Vladimir Karapetoff of Cornell University

analyzing the characteristics common to all of our familiar vectors. He drew the picture of a tensor as any set of quantities which form a system as a single entity, the system being the tensor and the set of elements the components of the tensor or generalized vector. These components are resolved or transformed in accordance with either 1 or 2 simple rules whenever the method of reckoning or system of resolution (the co-ordinate units of the mathematician) are altered. Generalized vectors were seen to be capable of any number of dimensions—for instance, 1 dimensional, as displacement; 2 dimensional, as area; etc. With the aid of this broadened conception and the criteria of transformation outlined, direct current in a network was seen to be a generalized "contravariant vector"; direct voltages a generalized "covariant vector"; the alternating currents and voltages of a polyphase system were seen to be generalized vectors with complex components; the currents (some direct current, some alternating current) in the various windings of a rotating machine and the velocity of its rotor were seen as the components of one (!) tensor; similarly, the voltages in the various windings and the torque on the rotor were seen to be the components of another single tensor; the impedance elements of any complicated system were seen to constitute a single "doubly covariant" 2-dimensional (that is, 2 circuit) tensor; simultaneous equations, which formerly were nothing but a collection of equations, were seen to be the equations of the components of a single generalized vector; and finally machine, circuit, and system connections, which yielded one set of currents (or voltages or impedances) from another set, were seen to be nothing but "transformation tensors." It then became obvious that a scheme of analysis which could view a complicated set of quantities comprehensively as a single system, a single generalized vector, and could write equations for it as for a single element and manipulate these equations as simple equations, could not help but be of very great value in the handling of complicated problems, and in writing generalized equations applicable to a great variety of types of equipment belonging to one general classification like "rotating machines," or, "static network," etc.

After the laying of this foundation, Professor Banesh Hoffman was called upon to build a mathematical superstructure. He explained tensor symbolism; developed the theory of "transformation" of tensors and gave examples of important tensors such as the "Christoffel symbol" and the "Riemann Christoffel curvature tensor," and their use in the "unified field theory" of Einstein.

Professor E. Weber was then called upon to present "The Tensor in Operational Methods," and he showed examples of the application of tensors in transmission network analysis, including transient phenomena, and pointed out useful fields of application of tensors in interference, cross-talk, stability, conductor vibration, etc.

Prof. J. L. Synge was then called upon to present "The Tensor in Physics." He explained the necessity of tensors in mathematical physics, and developed the equations of the "restricted theory of relativity" in tensor form. The equations of the electromagnetic field and related equations were exhibited in several comprehensive slides.

Turning back to engineers, the chairman called on Gabriel Kron and introduced him to the audience as a pioneer and a leading exponent in the application of tensor methods to electrical engineering problems. Mr. Kron spoke of the application of tensors to rotating machinery, and showed how the performance of rotating machines of any complicated structure and connections can be analyzed in a routine manner if the equations are set up in tensor form. He also pointed out how all the mathematical concepts of relativity dynamics appear in the study of rotating machinery. The utility of tensor concepts in field problems, where curvilinear co-ordinates appear, and in vacuum tube circuit analysis, was also mentioned.

An enthusiastic discussion followed.

Dr. C. L. Fortescue spoke of his interest in the subject and mentioned a number of books which he was studying at the present time, including one by Eddington and another by McConnel. He stressed the importance of approaching rotating machine problems from the point of view of the dynamical equations of Lagrange, which has actually been done by Kron in tensor form.

L. V. Bewley related his adventures in quest of an intelligible book on tensors, and mentioned "The Applications of the Absolute Differential Calculus" by McConnel as the more helpful reference. He expressed the opinion that time spent on the study of differential geometry (which is the subject matter covered by most of the tensor books) is time well spent, as it turns out that machine characteristics and equations are identical with various geometrical characteristics and equations.

Professor Guillemin and Doctor Barnes traced the beginnings of concepts of matrix algebra in the electrical literature with particular application to network synthesis studies.

W. H. Ingram expressed considerable skepticism about the value of relativity analogies to rotating machine studies and about the significance and utility of certain tensor concepts and equations as applied to rotating machine analysis.

P. L. Alger pointed out that the study of analogies can not fail but be highly instructive, and emphasized the fact that the basic equations of various scientific fields are generally identical.

H. H. Lauder recited his experience in the study of the bewildering array of the theories and equations of various rotating machines, and, how, when he became acquainted with tensors through Mr. Kron's work, the whole field of rotating machine theory and equations were at once unified and clarified for him, enabling him to make calculations for new types of machine at greatly reduced labor and thought. He found that with the same assumptions the tensor equation gave identical answers as other methods.

At 6:15 p.m., the chairman called on Prof. V. Karapetoff for concluding remarks. Professor Karapetoff declared this conference as one which will be remembered for many years to come as an historic session, ranking in character and importance with a few other historic sessions of the Institute, particularly the one in which the complex quantity theory and applications were first presented to the Institute as constituting a revolution in a-c calculations.

Research in Engineering Schools

By Vladimir Karapetoff, Chairman

The attendance at the conference on research in engineering schools was about 50 and would have been much larger if it were not for the conflicting conferences on schoo curricula and on tensor analysis. Professor Ernst Weber spoke on important research contributions by faculty members of colleges of electrical engineering in Germany, Austria, and Switzerland. The questior why original contributions to the science and art of electrical engineering by members of the faculties of American engineering schools lagged behind European schools was discussed from the floor by several teachers and practicing engineers. The consensus of opinion was that in both private and state-controlled colleges in this country emphasis is laid on elementary teaching rather than on research, and neither sufficient funds nor leisure is available for the latter. In Germany, where all technical universities are entirely controlled by the national government, head professors in each school are appointed from among mature practicing engineers who have already contributed to the progress of the art and who continue research in their chosen fields.

The committee on research of the A.I.E.E. has distributed lists of suggestions for research in colleges and some opinions were expressed at the conference as to the usefulness of such lists. The majority of those

present seemed to consider such lists of topics useful and desired their continuation. It was felt that student research should be promoted mainly for the development of interest and technique rather than for any important results to be expected.

Finally, the question of research and advanced study on the part of faculty members came for discussion, but apparently there were only a few in the audience who cared to contribute to this topic, so that the general impression was created that very little original research was going on among faculty members in this country. Dr. J. B. Whitehead of Johns Hopkins University spoke at length about his researches in cable insulation, the handicaps under which he is working, and the financial assistance received from the industry.

In closing the conference, Chairman Karapetoff expressed the opinion that apart from an individual interest in this or that research topic, the general function of the electrical engineering faculties should be to act as middlemen and interpreters between the profession and the industry on the one hand and the pure auxiliary sciences on the other hand. It is the duty of teachers of electrical engineering to follow closely at least one topic in the industry and also keep in touch with such branches of pure sciences as bear upon it. In this manner new developments in mathematics, physics, and chemistry are put in a form in which practicing engineers can use, and unsolved problems of the industry are put in such form that pure scientists can work on them. While a teacher in electrical engineering is concerned with the present status of the industry in his elementary teaching, he should have sufficient imagination and prophetic vision to anticipate the needs and the trends of the industry sufficiently far ahead to help create tools for the new developments and to prepare his best students for properly handling such new problems years hence.

Conductor Vibration

By A. E. Davison

Forty members attended the conference on conductor vibration held under the chairmanship of D. M. Simmons. Pre-arranged written discussions had reference largely to experience in the field which might be useful to members who were having similar experience, and who were seeking solutions for their problems. Among the prepared discussions were the following:

Pre-Stretching of A.C.S.R. Cables, A. E. Silver.

Oval-Shaped Cross-Section Conductors—Reports of Comparative Observations, M. E. Noyes and G. W. Stickley.

Analysis of Traveling Waves and Effects of Festoons Upon Them, W. B. Buchanan.

Conducting Clamps for Aluminum Cables; Life and Comparative Tests, E. Hansson.

Practical Long Time Experience With Loops and Festoons, A. H. Lawton.

Are Wire Failures Progressive Within Suppressive and Reinforcing Equipment? F. W. Deck.

Anti-Vibratory Clamps, C. L. Fortescue.

Experience With Vibration (Australia), E. Bate.

It is intended that these submissions along with some others will be mimeographed and circulated within the power transmission and distribution committee. It is also intended that members who are interested in any of the subjects mentioned may secure copies of the submission referred to, by writing to D. M. Simmons, chairman.

Discussions were introduced by E. M. Wright and W. S. Peterson, regarding experimental work and practice on the Pacific Coast. These discussions centered upon the methods used in connection with studies and experiments within wind tunnels upon vibration of cables, wherein an attempt is made to simulate field conditions.

Other features which came out in the general discussion were importance of details in the methods of clamping conductors, and such theoretical considerations as absorption within the span of cables and at discontinuities.

The introductory discussions which were submitted in writing are briefly as follows:

Considerable evidence has accumulated within at least one large operating system that redistribution of static stresses within A.C.S.R. conductors by pre-stretching adds materially to the life of the outer aluminum wires. They carry less static stresses, and therefore are in a position to resist successfully fortuitous bending stresses resulting from vibration.

A number of experiments have been made which indicate that there is a considerable alteration in the incidence of vibration under natural conditions, if oval-shaped conductors are used as compared with circular strand conductors. This statement is also true if 2 or more conductors are used for each phase regardless of whether they are fastened together at various points in the span so as to prevent wear. Although the incidence of vibration is altered, nevertheless, there are certain natural conditions by which vibration is set up within these specially designed conductors.

Some definite data was placed before the meeting regarding suppressive effects of festoons upon traveling waves and surges artificially introduced into conductors. These units compare favorably with field observations of suppressions under natural conditions where festoons have been used in a practical way. The better suppressions are of the order of 40 per cent.

Since a number of utilities are experiencing a reduction with age of conductivity at clamps, the recording of some experiments in Baltimore with A.C.S.R. splices over long periods would assist operators who have this problem before them. It was suggested that cold-flow pressing of joints with a liberal coating of red lead or some other compound which will reduce to a minimum oxidation within the splices is preferred practice. Twisted sleeves seem to lose their conductivity to a very considerable extent after a few years of use.

Representatives of 2 different utilities record experience as to the effectiveness of festoon or loop in reinforcing conductors where vibration troubles have developed, and in reducing to a negligible quantity over 10 year periods actual breaks of cables within a given system due to vibration.

Distribution Transformer Protection

By K. B. McEachron, Chairman

Approximately 35 engineers were in attendance and they discussed very freely certain aspects of protection of distribution transformers, with particular reference to the results of the interconnection of primary arrester ground and secondary neutral conductor. There was considerable discussion of the results of this interconnection and also a statement made that the secondary troubles were practically nil.

There was also discussion of the question of grounding the transformer tank and the part to be played by the isolating gap which is now being used on rural distribution transformers. Farm line transformer protection, and whether or not to use cutouts and lightning arresters, came in for their share of discussion. There was also a brief mention of the use of plain gap protection for distribution transformers and the relation which this might have to hazard from power currents to a customer connected in the secondary circuit.

Electrical Engineering Curricula and Educational Methods

By H. W. Bibber, Chairman

The conference on electrical engineering curricula and educational methods turned out to be quite in accord with the advance notice published in Electrical Engineering. Discussion was free, often spirited, and taken part in by nearly all present. At the conference, an agenda comprising some 26 questions was handed out. Those discussed were ones in which a large percentage of the group present were interested. The general trends of the discussion on the chosen topics follow.

Curricula

What policies can be adopted by schools to ensure a continuing process of inquiry, experiment, evaluation, and adjustment in the curriculum?

All agreed that changes were essential to meet the altered industrial and social conditions as well as technical advances. Changes in any one particular course or year of the program should not occur too often. Specific examples of policies were: preparation of a "5 year plan" of curriculum changes, the plan itself being subject to revision each year; review of the course content of all courses in the curriculum every 3 years with suggestions as to desirable revisions.

To what extent is an articulate philosophy of engineering education necessary in building curricula?

Many believed that more articulate discussion of the philosophy should take place in faculties. Agreement among men on the faculty may be assumed which does not exist, or one may be deceived as to how definite a philosophy certain instructors have. Great need exists for each teacher to see how what he does fits into the general plan.

It was suggested that an engineering course should aim at the cultivation of: desirable habits of mind or thought; moderate degrees of manual skill in drawing, the use of tools, and arranging apparatus in experimental set-ups; knowledge of the most fundamental principles of physics and a few facts about materials.

How much social orientation should be provided for engineering students, and how should it be done?

The general conclusion was that a considerable proportion of the curriculum (20

per cent was mentioned) should be devoted to social studies or the humanities. These should, however, be well taught and the professional departments should be much concerned as to the standards, methods, and objectives of instruction in such courses.

A strong plea was made for the consideration of an electrical engineering course as general education, in the light of the later careers of electrical engineering graduates, and the proportion of the total who actually follow technical electrical engineering work.

Since the electrical industry seeks men for positions in which the technical aspects of the job are not exacting, should departments of electrical engineering offer 2 curricula, 1 highly technical and the other providing more business subjects?

There is a growing tendency to recognize the fact that there are not only recognized divisions of the technical field, but there is a further superposed division of the entire field into a highly technical and a semitechnical part. A great many graduates land in jobs of the latter sort. Hence, many schools are providing technical options and administrative or business options in the junior and senior years. There was a feeling that administration of the combined business and electrical curriculum was better left in the hands of the electrical engineering department than to create a new "administrative engineering" course.

Educational Methods

How much time should be devoted to inspection trips and at what period of the 4 year curriculum should they come?

Many schools suffer from geographical location as far as good trips are concerned. However, the general feeling was that these trips are beneficial to students if not too concentrated. Usually going to local plants about once a week gives good results. The way in which trips are handled will largely determine their value. One procedure recommended was: (1) preparation by lecture or reading matter; (2) careful organization of trips, and sequence of steps in process, with sufficient guides so that there will be 1 guide to every 5 or 6 students; (3) tests to determine whether students have grasped important aspects of the plant; and (4) a report on some specified aspect, not a general report.

Does instruction by the project method, or the use of individualized assignment, prove successful in electrical courses?

If the number of students per teacher is not excessive this method may be very successful. It requires that courses be carefully laid out with adequate text reading material so that no lectures are necessary. Problems of graded difficulty are used. Laboratory work is successful if not too many men have to work in a group. Another aspect is to allow students to work out their own methods and schedule of laboratory work, requiring only that the results be turned in at a certain time.

Are comprehensive examinations of value only in honors courses or can they be employed with benefit in regular curricula?

Comprehensive examinations are being tried in some schools. There was one report to show that their value as an indicator of a student's grasp of a whole field was no better than the grades obtained in the individual courses in that field. As an instructional procedure, however, there seemed to be more agreement as to their value.

How successful are objective type examinations in electrical subjects in which so many principles are covered that problem type examinations are quite lengthy?

Objective type examinations were reported as successful when used to give a short quiz at the beginning of an hour, before new material was taken up. Doubt was expressed as to the value of long objective type tests, as the electrical field is one in which problems can be given that are objective in character, and which thoroughly explore a candidate's knowledge.

Is there merit or value in the use of a reading period of a week or 10 days free time before final examinations?

The reading period is a relatively new idea, and has not been widely tried out. There was one enthusiastic report of its value. In this case 3 weeks out of 15 were used as a reading period. Problem assignments were made for the period which involved the principles covered in text and lecture during the preceding 12 weeks. Many conferences with students were held during this period, and considerable benefits were evident.

Subcommittee May Issue Lightning Reference Book

Lightning and its effects on electric power systems and apparatus have been under investigation for more than 20 years and during that period many articles of interest and value have been published in technical literature thus providing a cumulative record of how the lightning problem has been attacked and partially solved. In the course of an extensive canvass of the literature being carried on by the lightning and insulator subcommittee of the A.I.E.E. power transmission and distribution committee, more than 250 papers and technical articles comprising some 1,300 printed pages have been indexed for the period 1918–35. In these papers are considered lightning characteristics, theory, laboratory and field tests, and protective devices used and their application and performance.

Recognizing the value of a conveniently bound volume in which would be reprinted all important papers that have been published on the subject of lightning, the subcommittee is considering the project of republishing these papers in one volume, provided there would be enough demand for this volume to enable the cost of production to be underwritten. If issued, the contemplated volume would be similar in size to the A.I.E.E. TRANSACTIONS, comprising some 1,300 9 by 12 inch pages, making up a book about $2^1/_2$ inches thick. This book would include the full text and illustrations of all lightning papers published from 1918 to 1935 by the A.I.E.E., in addition to those published in the *General Electric Review*, the *Electric Journal*, *Electrical World*, and the *Journal* of the Franklin Institute, and perhaps the English translations of a half dozen or so of the more important foreign papers. A comprehensive cross-reference index of authors' names and paper titles of course would be an important part of the volume.

Advance Orders Required

The work of producing this lightning reference book has reached the point where it is necessary to know definitely how many copies of such a book could be sold, before any further steps could be taken. It is tentatively estimated that the price of the volume to members of the Institute will range from \$5 up, depending upon the quantity to be produced and the number of papers to be included. It is expected that the book could be made available within one year.

For the benefit of interested persons and to assist the committee in its work, there is included on page 4 of the advertising section of this issue a convenient coupon that should be filled in and mailed at once.

Engineering Index to Solicit Funds

Organization of the Engineering Index National Committee is now sufficiently near completion to begin the actual solicitation of funds to be used in maintaining and expanding the Engineering Index, according to the announcement of its chairman, Dr. Frank B. Jewett (A'03, F'12, and past-president), president of Bell Telephone Laboratories, Inc., and vice president of the American Telephone and Telegraph Company. Plans for the expansion of this service were outlined in ELECTRICAL ENGINEERING for March 1935, page 345.

With regional subcommittees, the group includes more than 125 representative engineers, educators, and industrialists in various sections of the country. These members will approach, in the next few months, several hundred leading industrial corporations for the purpose of raising funds.

The keynote of the program has been stated by Dean Collins P. Bliss of the college of engineering of New York University, who is president of the Index. "The program which the fund will make possible will be carried out over a 5-year period. Not only will the continued usefulness of the Index be insured for that period, but by the end of that time it will have become wholly self-supporting. And, what is equally important, the Index will have been extended to an ever-widening circle of users through a reduction of the subscription rates until the rates have become only about half of what they are now."

The Engineering Index, for which the fund is being raised, is unique in its field. It may be described as a virtually complete catalog, with annotations, of current technical literature in all branches of engineering. It is complete, descriptive, prompt, and accurate. It is published in 2 forms: the complete annual volume; and the cumulative daily and weekly card service, including 280 subdivisions. Altogether, about 2,000 publications from 40 countries and in 20 languages are reviewed by the editors.

A.S.T.M. Publishes Index to Standards. The index to "A.S.T.M. Standards and Tentative Standards," as of January 1, 1935, has been issued by the American Society for Testing Materials. All of the A.S.T.M. specifications and tests are listed in the index alphabetically under subject headings. A list in numeric sequence of the serial designations is also included. Copies of the index are available from the American Society for Testing Materials, 260 South Broad Street, Philadelphia, Pa., or from the office of the American Standards Association, 29 West 39th Street, New York, N. Y.

Review of Legal Education for 1934. The annual "Review of Legal Education in the United States and Canada for the Year 1934" has been issued by the Carnegie Foundation for the Advancement of Teaching. Copies of this review may be had without charge upon application by mail or in person to the office of the Foundation, 522 Fifth Avenue, New York, N. Y. This review, a $7^1/_4$ by 10 inch booklet, some 70 pages in length, contains material of interest not only to the legal profession but to all educators and to those interested in the advancement of any profession. Schools of engineering and architecture, medicine, and law are considered in relation to such problems as state licensing of the individuals in these professions. Information also is presented on the historical development of universities, and the present status of professional members engaged in teaching. The data given on progress in bar admission requirements should be of value to engineers interested in licensing within their own profession.

Inventor of Schafer Method Dies. Sir Edward Albert Sharpey-Schafer, inventor of the Schafer method of artificial respiration, died March 30, 1935, in his Northumberland home in England, at the age of eighty-five. He had an international reputation in the fields of histology and physiology. He was distinguished for his discoveries regarding muscular action. In 1903 he devised the plan of resuscitation, also known as the "prone pressure" method, that has resulted in the saving of untold thousands of lives of persons apparently drowned or suffocated.

Chemical Industry Medal Awarded. The American section of the Society of Chemical Industry has announced that the award of the Chemical Industry Medal for 1935 has been made to Dr. E. R. Weidlein, director of the Mellon Institute of Research, Pittsburgh, Pa. The award is made annually to a person who has made a valuable application of chemical research to industry. Presentation of the medal will be made at a meeting of the Society in the fall.

American Engineering Council

Government Work Relief Program

Following are excerpts from the current "news letter" of American Engineering Council:

The Public Works Administration's recent news release affecting their portion of the work relief program is of particular interest to the engineering profession. The following changes in P.W.A. policy are emphasized for the benefit of engineers who may be affected.

The P.W.A. will now make advance payments of not more than 15 per cent of approved projects to enable the applicant to pay for architectural, engineering, planning and legal fees, cost of surveys, and other preliminary steps toward the launching of actual construction. It is no longer necessary for engineers and others furnishing professional services to wait for actual construction to begin before they can be paid for such services.

The responsibility for fixing wage rates on P.W.A. projects has been placed on the borrower and recipient of the grant made in connection with loans. This policy makes it easier to adjust wage rates to fit actual conditions in each community.

The regulation requiring 90 per cent of workers on each project to come from relief rolls is retained; but it is now stated that exceptions may be made on individual projects with the approval of Harry L. Hopkins.

All of these are important concessions likely to be of much assistance to the entire engineering profession.

Comparatively few opportunities for engineering employment are expected to develop in Washington, but much activity is expected in the states under the direction of state administrators of the Works Progress Administration. State organizations are being formed now and engineers seeking employment should be advised to contact the state administrators of the W.P.A. Instructions to the state administrators tell them not to engage in or make use of politics in connection with the execution of the work relief program, but appointments and assignments indicate that political sponsorship in the state may be as necessary as similar approval in Washington.

Engineers serving in administrative, consulting, professional, and supervisory capacities will be paid salaries and fees slightly less than those prevailing in the area where they are employed. Engineers on relief rolls must work for a maximum of $94 per month until they reach the place where they can "strike out for themselves."

The National Youth Administration, newly created, will provide part time employment for young people between the ages of 16 and 25 inclusive from "relief families." Consequently, this is not a program for unemployed young people from "non-relief families." High school students will be paid $6 per month, college students $15 per month, and those doing graduate work proportionately.

The Federal Housing Administration, under the plan of insuring loans for industrial rehabilitation, is pushing the possibilities of plant modernization. Our understanding is that there are many applications involving engineering improvements in machinery and equipment. The F.H.A. does not supply the money for these, but insures loans from other sources. This development is of considerable engineering significance in so far as it improves the possibilities of credit for loans for capital goods.

Survey of the Engineering Profession

The co-operative survey of the engineering profession was an assured success when the final deadline for receipt of questionnaires fell on July 8. Although it is as yet impossible to arrive at the exact number of blanks received, the number is ample to provide a good cross section of the engineering fraternity and to chart its situation through the depression years. As soon as the pressure of urgent federal work permits, the Bureau of Labor Statistics will tabulate the results so that complete data will be available.

Plans for the final tabulation are reported in an article appearing in the July 1935 number of *Civil Engineering*, by Allen P. Richmond, Jr., quoted in part as follows:

"While the exact details are not finally settled, it can be said in general that all the information in the questionnaire will be transferred to punched tabulating cards. The Bureau of Labor Statistics has devised code systems by which this information can be recorded by punching on a card $3^1/_4$ by $7^1/_4$ inches. Once punched, the cards are fed through sorting machines, which can be set to count any particular item desired. Correlations can be established at will, such as "How many civil engineers, graduates of a college with a bachelor's degree, are employed by municipal governments?" or "How many mechanical engineers working for the government are under civil service?" The Bureau is planning a series of such correlations according to states, and is selecting for the first tabulations the correlations which could be of the most immediate value. There is considerable congestion at the bureau because of the great demand for statistics on other employment situations, but it is now anticipated that the results should be available early this fall.

"One very interesting fact regarding the individual questionnaires is that almost all engineers signed their names, thus enabling apparent discrepancies to be straightened out and other necessary editorial work to be done by correspondence. The questionnaires received to date have been completely filled out, and it is anticipated that the resulting statistics will be authoritative."

Other A. E. C. Items

Council's inquiries as to the participation of engineering societies in public affairs have produced many interesting letters and suggestions which are helping in the compilation of a record of experience in this important field. Various explanations are offered as to the reason why engineers, having made an inestimable contribution to the general welfare in their technical work as individuals or as a profession, do not appear more in the general field of public affairs. The system of public affairs committees which Council is developing, together with the more aggressive action of engineering societies through the country, may tend to establish natural channels whereby engineers will be drawn into public matters with the aid of their colleagues, rather than fighting their way as individuals without help, encouragement, or objectives other than their own.

"The Formation of Capital," a new study by the Brookings Institution, completes the triology begun in "America's Capacity to Produce" and "America's Capacity to Consume," the findings of which are correlated and given added significance when viewed in their relation to the capital structure. As with the earlier reports, this study has been summarized in a pamphlet by the Maurice and Laura Falk Foundation of Pittsburgh, Pa. Council has a limited supply for distribution to engineers interested in new concepts of economy.

A study of business cycles has been reported in the July 1 bulletin of the National Bureau of Economic Research, 1819 Broadway, New York, N. Y. (price 50 cents). This analysis seeks to make use of the improved and extended accumulation of statistical data in recent years, in revising past theories of cyclical behavior.

News For State and Local Engineering Societies

Continuing along the lines of last month's letter, Council is giving separate attention to the work of state and local engineering groups. Many individual engineers and secretaries of societies have written to Council to report their news and it is hoped they will make this a regular practice. New types of public projects, promoted by engineering societies are particularly well worth knowing of at this time. For example:

A study of the existing foundations of the City of New Orleans is being carried out as a white-collar project under F.E.R.A., according to the secretary of the Louisiana Engineering Society, which group is sponsoring the program. Work is under supervision of 4 prominent engineers. Co-operation of engineers, architects, contractors, and public agencies has been enlisted in the assembly of data from borings and other investigations. The work is employing 25 engineers, architects, and draftsmen with additional clerical help. Engineering societies wishing to have similar work done in their areas may consult local relief and works progress officials.

Letters to the Editor

CONTRIBUTIONS to these columns are invited from Institute members and subscribers. They should be concise and may deal with technical papers, articles published in previous issues, or other subjects of some general interest and professional importance. ELECTRICAL ENGINEERING will endeavor to publish as many letters as possible, but of necessity reserves the right to publish them in whole or in part, or to reject them entirely.

ALL letters submitted for consideration should be the original typewritten copy, double spaced. Any illustrations submitted should be in duplicate, one copy to be an inked drawing but without lettering, and other to be lettered. Captions should be furnished for all illustrations.

STATEMENTS in these letters are expressly understood to be made by the writers; publication here in no wise constitutes endorsement or recognition by the American Institute of Electrical Engineers.

Emergency Practices in Resuscitation

To the Editor:

The following comments on artificial resuscitation were inspired by the paper in ELECTRICAL ENGINEERING for July 1933, pages 475–7, entitled "Resuscitation by Countershock" by W. B. Kouwenhoven and R. D. Hooker, which discusses in a very interesting manner the effect of electric current in the bodies of rats.

Obviously, experiments cannot be made on human beings to determine the effect of electric current through the body, or organs of the body, such as have been made on rats, so that we may be a long time learning more along this line or interpreting what we already know into practical use in emergencies.

However, in the field of emergency practices more should be written and discussed; not only in the hope of improving technique as we now understand it but of emphasizing the most important points of the best practice at present known, and teaching the whole public that technique and the principles back of it.

Very often we find trained first aiders, trained to go through certain motions, who do not know what those motions are intended to do in order to produce the final result; hence, in an emergency, confronted with complications or unexpected conditions, they are at a loss, confused, fail, or at least lose valuable time.

Everyone should fully understand that for artificial respiration the purpose is to so compress the abdomen as to force its contents gently up against the diaphragm, pushing it upward to form just enough compression in the chest (just a little more than atmospheric pressure) to cause the "air" to be "exhaled," not *forced* from the lungs. Operators can work intelligently only when they understand how the diaphragm raises and lowers normally, and what causes it to, and how the abdominal muscles assist by compression of the abdomen, for deep breathing.

They should understand more of how stimulants act on heart and respiratory nerve seats; yes, and how carbon dioxide, and oxygen, and oxygen-carbon dioxide mixture act; then they can be expected to administer these intelligently and avoid errors.

They should know more about blood circulation and its physiology and functions. They should know about the post-asphixia and post-strangulation pneumonia danger, too. They should know that an expulsion from the bowels is *not* a proof of death, but is to be expected as a probable result.

Let me relate briefly 3 cases to illustrate.

A lineman contacted a pair of 2,400 volt conductors and dropped unconscious in his safety strap. A fellow-worker, who had been *taught*, as well as trained, pushed the victim's head forward (face downward) where he hung; swung 3 parts of the hand line around the man and pole, and rhythmically squeezed his abdomen against the pole until others ascended and prepared to lower him, and continued on the way down. The time interval before help arrived, and other circumstances, were such that nothing else would have saved the man's life. Any other attempt would have failed.

Another lineman received a minor and momentary shock; a whole crew was at hand, and he was on the ground at the time; they started artificial respiration and called a doctor who came quickly. The doctor administered straight oxygen, instructing the men to continue while he went for something else. The colon expelled and the men considered, had heard, that that indicated death and quit, put him on his back. They remarked afterward that black areas continued to spread over the body, proving death.

Too much oxygen could inhibit voluntary breathing; with no stimulation of respiratory impulse or heart action, practically no circulation, and the body rapidly chilling. The spreading cyanosis should have been encouraging rather than discouraging, but should have suggested to a *taught* man that the body should be covered and the limbs rubbed to assist circulation, because what use is the oxygen drawn into the lungs if it is not distributed and the carbon dioxide returned and discharged?

A gumdrop lodged at the entrance to a man's windpipe; he was strangling. An executive at hand lost no time but, encirclng the man's abdomen, gave a quick squeeze with the desired result. If time had been lost waiting for a doctor or while other methods were tried, the lodgement probably would have become tightened and the doctor might have been too late, as has often been the result. This executive used the right idea instantly, without discussion, and probably saved the man's life.

At least the first case described above is the result of what I am advocating, the second case the result of manual training

only. The last case was not a comedy, at least it was not for a while for all present.

First aid textbooks do not do the trick, even when used. Medical men do not seem to realize that it *can* be done, this teaching of lay persons, but some day these things will be taught through required courses in every school in the country; why not now? Cases like the first and third here occur occasionally; those like the second are in the majority; can't we help?

We are not discussing what may be the result of passing a current of electricity through the heart to convert fibrillation, nor the use of adrenaline or heparin; but the layman can absorb, can understand, at least enough to govern him better; of much he is not now taught and retaught.

Many papers have been written; most contain material beyond the purpose now suggested here; all omit some things; *none* reach more than relatively few people; can our industry supply the need? I think it can and should. We should teach our employees in the electrical industry more, not just train them in a manual method; and we should see that the entire public is taught as much as possible; and finally, we should keep the knowledge before our men all the time, so in an emergency they will be ready to act at once, and regardless of circumstances.

Very truly yours,

J. M. Buswell
Electrical Inspector,
San Joaquin Light and Power Corp., Fresno, Calif.

Transmission Line Catenary Calculations

To the Editor:

The paper by D. O. Ehrenburg, "Transmission Line Catenary Calculations" (Electrical Engineering, July 1935, pages 719–28) develops a very original method of making sag and tension calculations. As far as I know his method of approach is entirely new, and I have not previously seen the point brought out that the values corresponding to horizontal span length and difference in elevation of supports for pure vertical loading are different with wind loading.

In reading over the paper, the following method of calculating stringing curves occurred to me as a substitute for the graphical method given in figure 3 of the paper. Referring to the accompanying table I, the first 5 items, which are for wind load conditions, are obtained by interpolation from table II of the paper, for the initial value of $Z = 0.082$, as determined in example I. The next 5 items are copied directly from table II, light load conditions.

Table I

Item								
With Wind Loading								
1. z	=	0.082						
2. $S\text{-}c$	=	0.539						
3. T_1'	=	8,672						
4. T_e'	=	8,312						
5. D'	=	11.4						
Cable Unloaded								
6. z	=		0.07	0.08	0.09	0.10	0.12	0.14
7. $S\text{-}c$	=		0.286	0.373	0.473	0.584	0.841	1.144
8. T_1	=		7,610	6,700	6,000	5,440	4,590	3,990
9. T_e	=		7,260	6,350	5,640	5,080	4,230	3,630
10. D	=		8.3	9.5	10.7	11.9	14.3	16.7
11. $T_e' - T_e$	=		1,052	1,962	2,672	3,232	4,082	4,682
12. S = item 2 + c	=		644.6					
13. $S\left(\frac{T_e' - T_e}{AE}\right)$	=		0.1055	0.1967	0.2679	0.3240	0.4092	0.4694
14. Items 7 − 2 + 13	=		−0.147	+0.031	0.202	0.369	0.711	1.074
15. Item 14 ÷ (αS)	=		−23.8	+5.0	32.7	59.8	115.0	174.0
16. $\theta = \theta_0$ + item 15	=		−13.8°	+15.0°	42.7°	69.8°	125.0°	184.0°

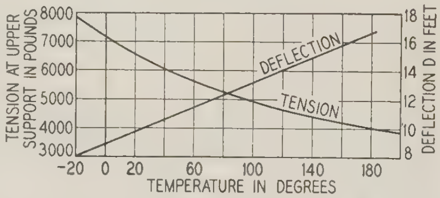


Fig. 1

The last 6 items are added to obtain temperatures without resorting to the graphical method. By plotting items 8 and 10 as ordinates against item 16 as abscissae, the stringing curves of the accompanying figure 1 are obtained.

Yours very truly,

H. J. McCracken, Jr. (A' 27)
Department of Water and Power,
City of Los Angeles, Calif.

To the Editor:

The method of calculating stringing curves proposed by H. J. McCracken, Jr., in table I of his "Letter to the Editor" (reproduced above), strikes me as being very ingenious. In reply to this letter, I would like to bring out the following points:

1. In my "example 1," the right-hand portion of the T_e' curve was plotted merely in order to find the maximum deflection, which occurs at wind load and 150 degrees Fahrenheit. In many problems I need only 2 points on the T_e' curve, as is the case in "example 2," for instance.

2. Mr. McCracken's value of T_1' is *nearly*, but not exactly, equal to the working tension. In table I of his letter, T_1' = 8,672 pounds, whereas the working tension is 8,650 pounds. However, this represents only a small error. In the case of "example 2" Mr. McCracken's method is even more accurate.

3. As it now stands, his method will work best in the case of long flat spans, worst in the case of very short steep spans.

4. For the first part of Mr. McCracken's calculations (wind load) my tables of functions cannot in general be used. To remedy this as well as the objection stated under 2, I would suggest that the wind-load calculations be carried out by graphical interpolation from values obtained from the tables of functions.

Very truly yours,

D. O. Ehrenburg
U. S. Bureau of Reclamation,
405 U. S. Custom House,
Denver, Colo.

Decrement Curves for Power Systems

To the Editor:

In the paper "Decrement Curves for Power Systems" by C. F. Dalziel in the February 1934 issue of Electrical Engineering, pages 331–8, the author presents a set of decrement curves intended to extend the range of application of the standard decrement curves, and one of the new factors introduced is the effect of resistance in calculating the magnitude and rate of decay of the fault current.

It would seem, however, that while this factor has been considered in relation to the a-c component, the effect on the rate of decay of the d-c component has been neglected, since the same time constant has been employed as in the case of the standard decrement curves where the direct component of fault current at any time t is given as

$$I_{dc} = \sqrt{2}\, i''\epsilon^{-t/0.15}$$

The initial value of the d-c component is, of course, determined by the point of the pressure wave at which the short circuit is applied, but thereafter it decays in an exponential manner corresponding to the time constant of the armature circuit, which is given by

$$T_a = \frac{x_2 + x_e}{2\pi f(r_a + r_e)}$$

where

x_2 = negative sequence reactance of machine

x_e = external reactance to the point of the fault

r_a = internal resistance of armature circuit

r_e = external resistance to the point of the fault

On figure 1 the writer has plotted the value of the d-c component at the end of the first half cycle expressed as a percentage of the initial value for various values of the ratio R/X, where

$$R = r_a + r_e$$
$$X = x_2 + x_e$$

This curve shows in a very striking manner the effect of resistance in reducing the peak value of the short-circuit current since even if the ratio R/X is as low as 0.2 the magnitude of the d-c component at the end of the first half cycle is reduced to 53

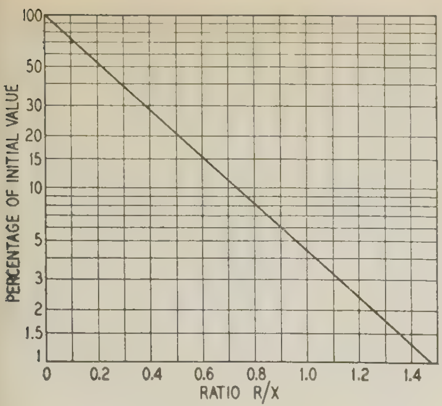


Fig. 1. Magnitude of d-c component at end of first half cycle

per cent of its initial value, while if the ratio R/X is 1.0 the magnitude of the d-c component at the end of the first half cycle is less than 5 per cent of its initial value and can be neglected.

It will be seen, therefore, that the effect of resistance on the rate of decay of the d-c component is very considerable, and the writer feels that the author's curves should be modified so as to take this effect into account.

Very truly yours,

W. H. Miller
139 Birchfields Road,
Followfield,
Manchester 14, England

To the Editor:

The curves given in "Decrement Curves for Power Systems," Electrical Engineering, February 1935, pages 331–8, were prepared to permit an estimate of the probable maximum and minimum short-circuit currents for various times after fault for 3 phase, line to line, and line to ground short circuits. Certain average machine and system constants were used in their preparation. Both the d-c time constant of the armature and the subtransient time constant were given average values, discussed by C. F. Wagner and S. H. Wright, "Calculation of Short Circuits on Power Systems," presented at the A.I.E.E. winter convention, New York, January 25–29, 1932. The values used were the same as those used by W. C. Hahn and C. F. Wagner, "Standard Decrement Curves," A.I.E.E. Transactions, volume 51, 1932, pages 353–61.

Mr. Miller's correction, introduced in his letter above, will affect the d-c component, and hence slightly reduce the maximum current curves only. This is a refinement, and could well be considered in decrement curves. However, since this time constant varies depending upon the type of fault considered, it will be necessary to prepare at least 2 sets of curves for estimating the maximum currents. At the time of constructing the curves, I did not think that such a refinement was justified, due to the great number of assumptions and approximations already made. It should be noted that the use of the published curves will result in safe values, and this correction will only reduce the maximum current curves slightly; therefore, pending the construction of more elaborate curves, I suggest that the curves be used as published. Special cases should then be reconsidered, using the actual time constants and resistances and reactances for the particular problem.

Very truly yours,

Charles F. Dalziel (A'33)
Associate in Elec. Engg. Dept.,
University of California, Berkeley

Confusion Exists in Rating of Low Loss Insulation

To the Editor:

May it be permitted through the medium of Electrical Engineering to call attention to a condition of confusion prevailing in the insulating material field. Although the efforts of the A.I.E.E. have resulted in good definitions of the electrical characteristics of insulating materials these have evidently not been put into practice by manufacturers of insulating materials.

In designing ultra-high frequency apparatus, requiring the best low loss insulating materials, it has been found that such confusion exists in the data published by the manufacturers that these data are completely valueless for comparative purposes. Whether this is due to carelessness on the part of engineers computing the values, or whether it is due to ignorance on the part of sales departments, is hard to say. In one case (see No. 3 in table I) it is clearly a mistake by the engineers making the test.

In cases where there are no special mechanical or thermal considerations the loss factor of a low loss insulating material may be used as a figure of merit. The loss factor $p' = k \tan \delta = k \cos \theta$; where k = dielectric constant and $\delta = 90 - \theta$. The term loss factor is proper as it takes in all variations of the material due to temperature and other physical and chemical factors. The loss per cubic centimeter may thus be expressed as:

$$p = 5.55\ 10^{-13} f\, e^2\, k \tan \delta \qquad (1)$$

or

$$p = 5.55\ 10^{-13} f\, e^2\, p' = A\, p' \qquad (2)$$

where f = frequency, e = voltage gradient = volts per centimeter, and A is a constant. For given conditions p' is the only variable in this loss equation and may thus rightly be called the loss factor.

In table I have been compiled values of power factor, dielectric constant and loss factor of the best commonly used low loss insulating materials. As may be seen from columns 5 and 6 representing, respectively, the loss factor as given by the manufacturer and the actual loss factor computed from power factor and dielectric constant, there is considerable variation. It is often impractical for the designer of electrical apparatus to make his own tests on the various materials, and one must rely on such data as furnished by the manufacturer of the insulating material. From this table it is easily seen that if one is to meet the exacting specifications laid down by modern requirements the data available are worse than valueless in that one may be led into making serious mistakes by following same. In interviewing the sales engineers of some of these manufacturers one is impressed by the fact that every one claims superiority for his product over all the others. Some manufacturers even publish comparative data of doubtful value due to its inexact and careless preparation.

Due to the growth of short-wave radio communication and new materials developed the above problems have become of increasing importance. Even the latest handbooks do not give reliable data on all materials. It seems therefore that this should be a welcome opportunity for the A.I.E.E. to compile and publish reliable comparative data. It may be stated as a mitigating circumstance for the manufacturers of insulating materials that in most cases the errors shown in the table are to their own disadvantage. It further illuminates how unfamiliar most engineers are with the proper use of the power factor. It would seem from this that the practice of stating the power factor in per cent should be entirely discontinued as it is here that most mistakes are made.

Very truly yours,

Magnus Björndal (A'25)
807 Summit Ave.,
Jersey City, N. J.

Table I

1 No.	2 Material	3 Power Factor 1000 kc. 17 deg C.	4 Diel. Constant	5 Loss Factor Given by Mfrs.	6 Correct Loss Factor	7 Source of Information
1	Isolantite	0.00181	6.1	1.05	0.011	Isolantite Bull. 100-F.
2	Mycalex	0.003	6.1		0.0183	"Mycalex the Ins." Bull.
3	Mycalex	0.0017	6.2	1.05	0.0105	El. Test. Lab. Report No. 163, 286; 6-2-32.
4	Mycalex	0.0063	6.1		0.0384	Nat. Phys. Lab., London.
5	Victron "AA"	0.0006	2.5	0.15	0.0015	*Insulation Engineer*, v. I, Dec. 1933, No. 2.
6	Victron "AA"	0.0008	3.0	0.24	0.0024	"
7	Victron "K"	0.0012	3.5	0.42	0.0042	"
8	Victron "K"	0.0015	4.0	0.60	0.006	"
9	Hard rubber			1.6	0.16	"
10	Bakelite			3.6	0.36	"
11	XIB rubber	0.00414	3.74	0.42*	0.0155	Am. Hard Rubber Co.
12	X2B rubber	0.00386	4.3	0.39*	0.0166	"
13	Bakelite Gr. XXX	0.035	5.0	0.18	0.175	Synthane Corp. Bull.
14	Pyrex	0.00418	4.9		0.0205	Std. Handbook for Elec. Engrs., p. 485
15	Mycalex	0.002 (100 kc.)	8.0		0.016	"

* Designated as "power factor loss" by the manufacturer, but apparently is the power factor in per cent.

Personal Items

C. A. Adams (A'94, F'13, member for life and past-president) Lawrence professor of engineering, Harvard University, Cambridge, Mass., has, with his co-authors J. C. Hodge and M. A. MacKusick, received honorable mention in connection with the award of the 1934 A.I.E.E. national prize for best paper in theory and research, for their paper "High Frequency Induction Furnaces." Professor Adams was born in 1868 in Cleveland, Ohio, and graduated from Case School of Applied Science in 1890 with the degree of bachelor of science. In that year he became a draftsman with the Brush Electric Company, and in 1891 joined the teaching staff of Harvard, where he has remained since that date. At Harvard University, he was first an instructor, becoming assistant professor in 1896, and professor in 1906. Since 1914 he has held the chair of Lawrence professor of engineering. From 1919 to 1921 he was also dean of the engineering school. In 1905 he received the degree of electrical engineer from the graduate school, and in 1925 the university bestowed upon him the honorary degree of doctor of engineering. Professor Adams has carried on an extensive consulting practice and has conducted numerous investigations on electrical machinery, being particularly active in the electric welding field. He has served the Institute in numerous capacities, and was its president 1918–19. Among the many committees on which he has served are the standards and electric welding committees, of which he has been a member during the Institute's year just ending.

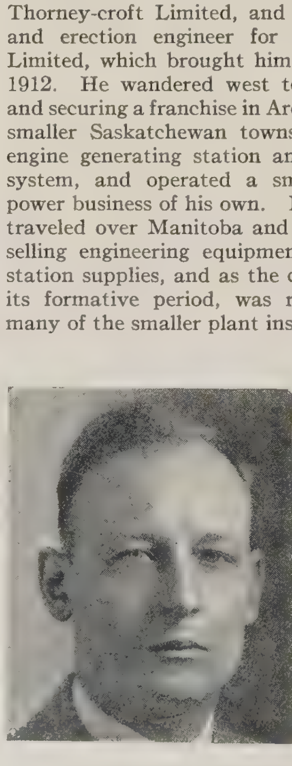
E. H. Bancker (A'23, M'30) central station engineering department, General Electric Company, Schenectady, N. Y., has been awarded the 1934 A.I.E.E. North Eastern District prize for best paper, jointly with his co-author E. M. Hunter (A'28), for their paper "Distance Relay Action During Oscillations." Mr. Bancker was born at Brooklyn, N. Y., in 1896, and after receiving the degree of bachelor of arts from Williams College in 1916, attended Massachusetts Institute of Technology for graduate work, there receiving the degree of bachelor of science in 1918. In 1919 he entered the testing department of the General Electric Company. In 1920 he spent a few months as assistant in the laboratory at M.I.T., becoming head of railway control tests for the General Electric Company in that year. From 1922 to 1926, he was engaged on relay design and application in the switchgear engineering department of the company, having charge of the design of induction type relays. After several months with the Turners Falls Electric and Power Company, he returned to the General Electric Company in 1927, entering the central station engineering department, where he has since remained. In this position he has specialized in power system protection, and in evolving methods of calculating power system stability. Mr. Bancker previously presented a paper before the Institute.

E. M. Hunter (A'28) central station engineering department, General Electric Company, Schenectady, N. Y., has been awarded the 1934 A.I.E.E. North Eastern District prize for best paper, jointly with his co-author, E. H. Bancker (A'23, M'30) for their paper "Distance Relay Action During Oscillations." Mr. Hunter was born in Portsmouth, N. H., in 1902, going to Worcester Polytechnic Institute for his engineering training. That institute awarded him the degree of bachelor of science in 1926, and the degree of electrical engineer in 1930. Mr. Hunter spent 15 months on the test course of the General Electric Company at Schenectady between his junior and senior years in college, and after graduation in 1926, continued for a few months on the test course of the company at Pittsfield, Mass., and at Schenectady. Later that year he entered the turbine generator engineering department of the company in Schenectady. Since 1928 he has been in the central station engineering department. For graduate work at Union College, Mr. Hunter was awarded the degree of master of science in 1931. He has previously presented papers before the Institute.

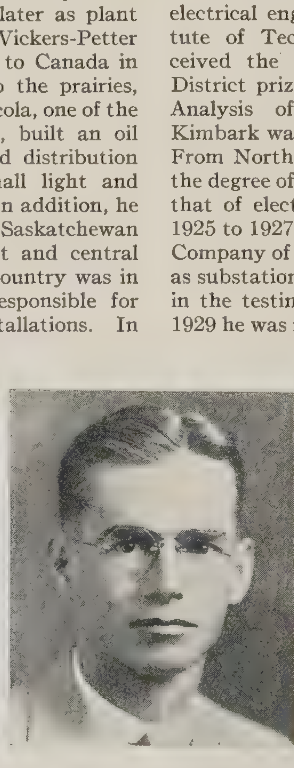
H. F. Forbes-Roberts (A'25) Saskatchewan manager of the Montreal Engineering Company, with headquarters in Regina, Canada, has been awarded the 1934 A.I.E.E. Canada District prize for best paper, for his paper "The British National Grid System." Mr. Forbes-Roberts was born on the Isle of Wight, off the southwest coast of England, and was educated at St. Johns College there. He served as pupil engineer with John I. Thorney-croft Limited, and later as plant and erection engineer for Vickers-Petter Limited, which brought him to Canada in 1912. He wandered west to the prairies, and securing a franchise in Arcola, one of the smaller Saskatchewan towns, built an oil engine generating station and distribution system, and operated a small light and power business of his own. In addition, he traveled over Manitoba and Saskatchewan selling engineering equipment and central station supplies, and as the country was in its formative period, was responsible for many of the smaller plant installations. In 1927 he joined the Calgary Power Company when they commenced operations in Saskatchewan, and was engaged on the construction of their system there. In Saskatchewan this utility is known as the Montreal Engineering Company, and supplies some 50 centers with electrical service. He is now in charge of the company's operations in the province. This year he is president of the Regina Board of Trade.

C. K. Gieringer (A'35) development engineer, Liebel-Flarsheim Company, Cincinnati, Ohio, has been awarded the 1934 Middle Eastern District prize for initial paper for his paper "A New A-C Null Indicator." Mr. Gieringer was born in 1907 at Miamitown, Ohio. He attended the University of Cincinnati from 1925 to 1928, and was enrolled in the co-operative electrical engineering course. As a co-operative student he established his own contracting concern. In 1928 he moved to Arizona and attended the University of Arizona, studying business. He returned to the University of Cincinnati in 1930 and at the same time became a co-operative student employee in the research laboratory of the Detroit (Mich.) Edison Company. He received the degree of electrical engineer in 1932. During the ensuing 2 years he was a teaching fellow at the University of Cincinnati, receiving the degree of master of science in electrical engineering in 1934. Since 1934 he has been employed as development engineer of physical therapy apparatus for the Liebel-Flarsheim Company. He is a member of Eta Kappa Nu, Tau Beta Pi, Sigma Xi, and the Institute of Radio Engineers. The prize winning paper was written while he was a teaching fellow at the University of Cincinnati.

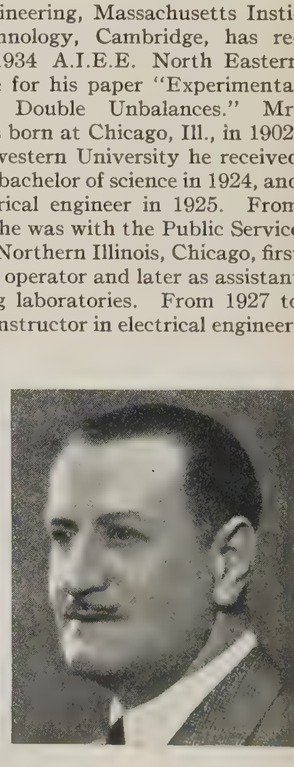
E. W. Kimbark (A'27, M'35) assistant in electrical engineering, Massachusetts Institute of Technology, Cambridge, has received the 1934 A.I.E.E. North Eastern District prize for his paper "Experimental Analysis of Double Unbalances." Mr. Kimbark was born at Chicago, Ill., in 1902. From Northwestern University he received the degree of bachelor of science in 1924, and that of electrical engineer in 1925. From 1925 to 1927 he was with the Public Service Company of Northern Illinois, Chicago, first as substation operator and later as assistant in the testing laboratories. From 1927 to 1929 he was instructor in electrical engineer-



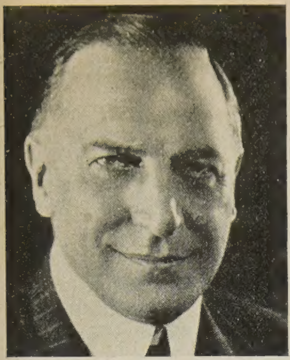
E. W. KIMBARK



C. K. GIERINGER



H. FORBES-ROBERTS



L. A. S. WOOD

E. M. HUNTER

E. H. BANCKER

ing at the University of California, Berkeley, becoming assistant curator, division of power, of the Museum of Science and Industry, Chicago, in 1929. During 1932–33, he studied at Massachusetts Institute of Technology, Cambridge, receiving the degree of master of science in electrical engineering in 1933. The following year he was research assistant in electrical engineering at M.I.T., becoming an assistant in electrical engineering in 1934.

L. A. S. Wood (M'24) chief commercial lighting engineer, Westinghouse Electric and Manufacturing Company, New York, N. Y., has been elected president of the Illuminating Engineering Society, assuming office October 1, 1935. He was born in London, England, and was educated at City of London School and the University of London. In 1895 he became connected with the Edison and Swan United Electric Light Company, Ltd., London, and, specializing in illumination, later became special representative handling street lighting problems in Europe for the Union Electric Company of London. Mr. Wood came to the United States in 1911 in connection with the introduction of the flame carbon arc lamp, and was shortly afterwards appointed arc lamp expert for the Westinghouse company at East Pittsburgh. From 1915 to 1920 he was with the George Cutter Company, South Bend, Ind., becoming district sales manager. When this company was absorbed by the Westinghouse company, Mr. Wood was made manager of the street lighting department, and in connection with this work traveled extensively, maintaining his headquarters at South Bend. At the time of his recent transfer to New York he was manager of the exterior lighting section at Cleveland, Ohio. An Institute paper by him was published recently.

James Burke (A'93, M'03, F'13, and member for life) has retired from the Burke Electric Company, Erie, Pa., of which he was chairman of the board of directors, after more than 30 years as active head of the company. Mr. Burke was born in London, England, and was with the General Electric Company and its predecessors at Schenectady, N. Y., from 1889 to 1894. He then engaged in consulting engineering, but shortly accepted the position of technical director and chief engineer with the Bergmann Elektromotoren und Dynamo Werke, Berlin, Germany. He returned to the United States in 1902, and 2 years later the company bearing his name was formed. Mr. Burke is known for his ability as an inventor, having received a number of patents which include designs for a generator winding by which 3-wire service from a single machine was made possible and a motor for operation on either a-c or d-c supply. His society memberships include The American Society of Mechanical Engineers, the American Welding Society, of which he is a charter member, and the Edison Pioneers. Mr. Burke was a member of the standards committee of the Institute 1914–19, and of the electrical machinery committee 1917–27. He served on the U.S. National Committee of the International Electrotechnical Commission as representative of the National Electrical Manufacturers Association from 1914 to 1930, and as representative for the Institute 1930–32.

E. R. Northmore (A'07, M'13, F'28, and past vice president) superintendent of electrical distribution, Los Angeles Gas and Electric Corporation, Los Angeles, Calif., was recently presented with a parchment scroll in commemoration of 42 years continuous service with the company. Mr. Northmore went to California in 1876, and was employed as an apprentice by the Los Angeles Electric Company in 1893, becoming superintendent of distribution in 1902. He served the Institute as a vice president 1927–29, and as a member of the power transmission and distribution committee 1928–29.

F. B. Crosby (A'07) electrical engineer, Morgan Construction Company, Worcester, Mass., has been elected president of the Worcester Engineering Society. Mr. Crosby was a member of the Institute's committee on applications to iron and steel production (formerly iron and steel industry committee) 1914–34, serving as chairman 1923–26, and during the latter period was also a member of the meetings and papers (now technical program) committee. He is a past-secretary of the local Section, and is a member of the Association of Iron and Steel Electrical Engineers.

W. S. Barstow (A'94, M'99, F'12, and Life Member) retired former president of W. S. Barstow and Company, and member of Barstow, Tyng and Company, Inc., New York, N. Y., has received the honorary degree of doctor of science from Columbia University, New York, in recognition of his "long, devoted, and highly successful career as electrical engineer and organizer of engineering knowledge in its manifold applications to the public service and public welfare.". Doctor Barstow is a representative of the Institute on the library board of United Engineering Trustees, Inc.

E. B. Meyer (A'05, M'13, F'27, and president) chief engineer, Public Service Electric and Gas Company, Newark, N. J., has been appointed a representative of the Institute upon American Engineering Council for one year, following the policy adopted 2 years ago of the president serving as a representative during his term of office. Mr. Meyer was recently elected to serve the New York Electrical Society for the year 1935–36 as its first vice president.

K. A. Hawley (A'09, M'12, F'35) who has been chief engineer for the Locke Insulator Company, Baltimore, Md., since 1922, is now with the newly formed Victor Insulators, Inc., at Victor, N. Y. Mr. Hawley is a member of the Institute's power transmission and distribution committee, having served on it since 1930, and recently presented a paper on insulators to the Institute.

W. J. Shackelton (A'12) development engineer, Bell Telephone Laboratories, Inc., New York, N. Y., has been appointed to represent the American Society for Testing Materials on the new sectional committee on electric and magnetic magnitudes and units. Mr. Shackelton has been a member of the Institute's instruments and measurements committee since 1930.

B. M. Brigman (M'28) dean, Speed Scientific School, University of Louisville, Louisville, Ky., has been appointed a member of the city planning and zoning commission by the mayor, the term expiring 1938. Since 1930 Dean Brigman has been a member of the Institute's committee on legislation affecting the engineering profession.

T. M. Keiller (M'34) for the past year superintendent of transmission and distribution for the El Paso Electric Company, El Paso, Texas, has been appointed to a similar position at Navasota with the Gulf States Utilities Company. Mr. Keiller has been connected with companies in the Stone and Webster group since 1922.

V. L. Hollister (A'08, M'32) consulting engineer, Hollister Engineering Company, Lincoln, Nebraska, has been named engineer for the Nebraska State Railway Commission. Mr. Hollister served on the Institute's power transmission and distribution committee 1928–29, and on the membership committee 1931–32.

H. L. Curtis (A'21, F'26) principal physicist, National Bureau of Standards, Washington, D. C., has been appointed to represent the American Society for Testing Materials on the new sectional committee

on electric and magnetic magnitudes and units.

HARVEY FLETCHER (M'23, F'30) physical research director, Bell Telephone Laboratories, Inc., New York, N. Y., has been elected to membership in the National Academy of Sciences. Papers on high quality transmission and auditory perspective have been presented to the Institute by him.

W. R. THORSON (A'26) former engineer with Burns and McDonnell, consulting engineers, Kansas City, Mo., has become general manager of the municipal light and power plant at Muscatine, Iowa, which is the largest municipally owned electric utility in that state.

J. D. UNDERHILL (A'20) has been made vice president of The Okonite Company, the Okonite-Callender Company, and Hazard Insulated Wire Works, with headquarters at New York, N. Y. Mr. Underhill until recently was sales manager at New York.

J. M. ROBERTSON (A'01) consulting engineer, Montreal, Que., Can., has been appointed by the Montreal Board of Trade as its representative on the commission that is to study the need of a sewage disposal plant for the city.

STERLING BECKWITH (A'34) formerly connected with the Metropolitan Water District of Southern California, Los Angeles, is now engaged in a-c machine design in the electrical department of Allis-Chalmers Manufacturing Company, Milwaukee, Wis.

GEORGE NOBLE (A'34) formerly electrician in charge of Mountain Park Collieries, Ltd., Mountain Park, Alberta, Can., has accepted an appointment as electrical engineer for the Cadomin Coal Company, Ltd., Cadomin, Alberta, Can.

F. J. SOMERS (A'31) who has been with Television Laboratories, Ltd., San Francisco, Calif., is now with its successor, Farnsworth Television Incorporated, at Philadelphia, Pa.

HERBERT HOOVER (HM'29) Palo Alto, Calif., was granted the honorary degree of doctor of laws by Drake University, Des Moines, Iowa, at commencement exercises June 3, 1935.

R. A. HOPKINS (A'19) salesman, Westinghouse Electric and Manufacturing Company, Los Angeles, Calif., was recently elected a vice president of the Los Angeles Electric Club.

H. L. CALDWELL (A'07, F'20) engineer of distribution, operating division, Bureau of Power and Light, Los Angeles, Calif., was recently elected a vice president of the Los Angeles Electric Club.

J. G. ROLLOW (A'26, M'33) chief electrical engineer, Los Angeles Gas and Electric Corporation, Los Angeles, Calif., was recently elected to the executive committee of the Los Angeles Electric Club.

J. S. JONES (A'19, M'19, F'25) formerly assistant to president, Consolidated Laundries Corporation, New York, N. Y., is now with American Machine and Metals, Inc., New York.

W. H. JUNKELMAN (A'27) who has recently been with RCA Photophone, Inc. New York, N. Y., is now commercial engineer for the New York (N. Y.) Edison Company.

F. M. KINNEY (A'32) formerly in the electrical engineering department of The Hoover Company, North Canton, Ohio, is now electrical engineer with The Buckeye Portable Tool Company at Dayton.

C. G. GRIMES (A'33) lieutenant, U. S. Navy, who has been electrical officer of the U.S.S. New Mexico, is now in the bureau of engineering of the Navy Department, Washington, D. C.

W. J. TIENKEN, JR. (A'26) sales engineer formerly with the Electric Storage Battery Company, New York, N. Y., is now with the Morganite Brush Company, Long Island City, N. Y.

R. B. STEINMETZ (A'26) is now district engineer for the Anaconda Wire and Cable Company at Boston, Mass., having previously been in the company's office at New York, N. Y.

F. J. LYDEN (A'26) electrical engineer formerly with the Baldor Electric Company, St. Louis, Mo., is now in the welding division of J. D. Adams Company, Indianapolis, Ind.

M. K. TOEPPEN (A'21, M'21) who recently resigned as chief consulting engineer of the Michigan Public Utilities Commission, is now with the Federal Communications Commission at Washington, D. C.

WILLIAM BOLSTER (A'33) former chief electrician with the United Fruit Company, New York N. Y., is now employed by the Sperry Gyroscope Company, Brooklyn, N. Y., as compass engineer.

N. L. GREGG, JR. (A'34) formerly in the electrical drafting department, Newport News Shipbuilding and Dry Dock Company, Newport News, Va., is now with the Union Power Company at Mullens, W. Va.

CONRAD CREIM (A'34) Metropolitan Water District of Southern California, who has been at Banning, is now engaged in electrical maintenance at Hemet.

L. L. ROBINSON (A'31) recently became associated with the Gustav Hirsch organization in Columbus, Ohio, consulting engineers engaged primarily in telephone work.

H. G. WESTON (A'30) telephone engineer formerly with C. A. McKee, New York, N. Y., is now with James O. Oliver and Company, Inc., New York.

D. W. REEVES (A'28) former superintendent of sales, Gulf States Utilities Company, Lake Charles, La., is now power engineer at Beaumont, Texas.

C. E. SODERBAUM (A'24) former operating engineer, Motala Kraftwerk, Motala, Sweden, is now director of the Porjus Kraftwerk, Porjus.

R. E. MCADAM (A'34) is now an instrument designer in the development department of the Eastman Kodak Company, Rochester, N. Y.

F. E. SNELL (A'23) who has been assistant superintendent of power, Cleveland Railway Company, Cleveland, Ohio, has been appointed superintendent of power.

J. G. KUHN (A'30) is now with Kinner Airplane and Motor Company, Glendale, Calif., as engineer.

J. S. HAGAN (A'20, M'31) has engaged in consulting engineering practice in St. Louis, Mo.

H. H. MOODY (A'34) is now employed in the geophysics department of the Continental Oil Company at Ponca City, Okla.

A. L. KISSEL (A'26) is now a field engineer with Utility Consumers Service, Pittsburgh, Pa.

R. B. MACLAUGHLIN (A'32) Acme Meter Service Corporation, has been transferred from Boston, Mass., to Pittsburgh, Pa.

M. G. TAYLOR (A'31) manager, Venezuela Power Company, Ltd., who has been at Barquisimeto, is now at Maracaibo.

J. C. DONAHUE (A'23) Rockland Light and Power Company, who has been at Middletown, N. Y., is now at Nyack, N. Y.

S. C. FRASER (A'30) is now president of Neon Sign Supply, Inc., Milwaukee, Wis.

Obituary

SERGIUS PAUL GRACE (A'03, F'21) assistant vice president of Bell Telephone Laboratories, Inc., New York, N. Y., died suddenly June 23, 1935. Doctor Grace was born at Farmington, Mich., on October 11, 1875. He graduated from the University of Michigan in 1896 with the degree of bachelor of science in electrical engineering, and started work that year for the Detroit (Mich.) Telephone Company, making important contributions to its problem of corrosion in underground cable sheaths. Between 1898 and 1900 he was chief engineer and operating manager of the People's Independent Telephone Company of New Orleans. After a few months as superin-

tendent of equipment for the Southwestern Bell Telephone Company of Texas, he became equipment engineer of the Erie Bell Telephone System in 1901, and becoming general superintendent of the Beaumont Independent Telephone Company of Texas later that year. In 1902 he became chief engineer of the Interstate Independent Telephone Company of New Jersey, later that year becoming assistant engineer for the American Telephone and Telegraph Company, whose headquarters were then at Boston, Mass. From 1902 to 1908, he was chief engineer of the Central District Telephone Company, Pittsburgh, Pa., and from 1908 to 1913 he was general superintendent of plant of the Central District company. During this period, when local telephone lines were being changed from open wires to aerial cables, Doctor Grace made many notable contributions to this development. In 1913 he became a consulting telephone engineer, at New York, N. Y., and the next year became chief telephone engineer for the Public Service Commission of the state of New York. From 1915 to 1920, he was assistant to the chief engineer of the New York Telephone Company and other companies of the Bell system. After a few months as assistant to the president of the Standard Chemical Company of Pittsburgh in 1920, he became advisory engineer to the general counsel of the New York Telephone Company. In 1921 he was appointed engineer on foreign wire relations for the American Telephone and Telegraph Company; in 1922, construction engineer, New York Telephone Company; later in 1922, general superintendent of by-products, American Telephone and Telegraph Company; in 1924, commercial development engineer of the Western Electric Company; in 1925, communication development engineer of the Bell Telephone Laboratories; in 1927, general commercial engineer of the laboratories; and in 1928 assistant vice president of the laboratories, which position he held until the time of his death. Doctor Grace was well known throughout the country for his lectures and demonstrations on the telephone system and its by-products. He was a past-president of the New York Electrical Society and of the Engineers Society of Western Pennsylvania. He was a member of the Engineers' Club of New York. He had been honored with the degree of doctor of engineering from the University of Michigan, and that of doctor of law from Notre Dame University. Doctor Grace had served the Institute as a member of its board of examiners, and on committees on education, meetings and papers (now technical program), and communication.

Richard Fleming (A'02) retired, Burlingame, Calif., died June 16, 1935. He was born in Ireland on May 23, 1866, and acquired his technical education by an extensive series of private courses. During the period 1886 to 1889, he was in various capacities in different central stations and street railway plants in different parts of the United States. Between 1889 and 1891, he was manager of the Olympia (Wash.) Light and Power Company, and assistant district engineer of the Edison General Electric Company at Portland, Ore., engaged on the installation of some of the first hydroelectric plants in the northwest. From 1891 to 1893 he was superintendent and chief engineer of the Rockford (Ill.) Electric and Manufacturing Company, designing and building dynamos and motors. In 1894 he was employed by the U.S. government in charge of electrical and mechanical work in fitting out a number of ships, including the battleship "Maine," and for the next 2 years was with the Fleming-Spence Electric Company as manager and engineer. In 1896, he entered the General Electric Company, West Lynn, Mass., remaining with the company until 1909, engaged on the design of arc lighting and other equipment; during this period he made pioneering inventions in connection with the enclosed flaming arc lamp. During 1909–10, he was a consulting engineer in New York, N. Y., engaged on the development of a gasoline-electric railway car. During 1911–13, he was plant manager of the Adams-Bagnal Electric Company, Cleveland, Ohio, and during 1913–14, was plant manager of Fairbanks-Morse Company, Indianapolis, Ind. During 1916–25, he was engaged in oil refining engineering in the development of an oil cracking process which was later used throughout the country. The Richard Fleming Company was organized for the furtherance of this work. In 1925 Mr. Fleming retired, residing at Burlingame, Calif., since that time. During the war (1917–18) he was inspector of smokeless powder plants for the U.S. government.

Joseph Showalter (M'21) who for the past 14 years had been sales engineer for the Canadian Westinghouse Company, Ltd., Toronto, Ontario, Canada, died June 5, 1935. Mr. Showalter was born April 25, 1880, at Gardner, Ill. His electrical and technical education was privately acquired. Between 1900 and 1902, he served the Diamond Meter Company and the Peoria Gas and Electric Company of Peoria, Ill., in various capacities, being in charge of the meter department during part of this period. Between 1902 and 1904, he was superintendent of the electrical and testing departments of the Duncan Electrical Manufacturing Company, instrument and meter manufacturers, Lafayette, Ind., and between 1904 and 1906 was engaged by the Western Electrical Manufacturing company, Berlin, Ontario, Canada, to design and manufacture a line of electric watthour meters. Between 1906 and 1909, he was engaged in electrical contracting, maintaining his headquarters at Berlin, Canada. In 1909, he became chief engineer for Ferranti Electrical Company, Ltd., Toronto, the Canadian branch of Ferranti, Limited, of England. He took this position when the Canadian branch was started, and was largely responsible for the development of a large business. In 1920, he left the Ferranti company to undertake practice as an electrical engineer. Shortly thereafter he became sales engineer of the Toronto office of the Canadian Westinghouse Company, remaining in this position until recently. Mr. Showalter had presented several papers before engineering associations and had served the Institute on its membership committee 1928–29.

Arthur Dudley Buzby (A'24) consulting engineer, Los Angeles, Calif., died May 26, 1935. Mr. Buzby was born June 30, 1889 at Montreal, Quebec, Canada. After 3 years of study at the school of science at Princeton University, he attending Valparaiso University, receiving the degree of civil engineer in 1911. He then took post graduate work in Massachusetts Institute of Technology for one year. During 1912–13, he was structural draftsman for Post and McCord, New York, N. Y., and during 1913–15 was bridge designer for the Erie Railroad. From 1915 to 1918 he was with the Chile Exploration Company and the Braden Copper Company, being successively, structural engineer, general designer, second assistant designing engineer, and principal assistant to the designing engineer. From 1918 to 1919, he was in the aviation service of the U.S. Signal Corps as experimental engineer, attached to the French Aviation Mission, in charge of design, construction, and development of combat planes. During 1919–20, he was again with the Chile Exploration Company and Braden Copper Company, resuming his previous duties. For several years following 1920 he was technical consultant for the Wellman-Seaver-Morgan Company, New York, N. Y., engaged on the design and application of a variety of mechanical equipment. He then became a consulting engineer at Jacksonville, Fla., being a member of the firm of DeSaussure and Buzby for several years. For the past few years he has been a consulting engineer at Los Angeles, Calif.

John J. Howard (M'21) electrical engineer, The Connecticut Company, New Haven, died June 3, 1935. Mr. Howard was born at New Haven, Conn., November 26, 1880, and graduated from the electrical engineering course at Yale University in 1903. Upon graduation, he entered the apprenticeship course of the Allis-Chalmers Company (then the Bullock Company) Cincinnati, Ohio, entering the testing department in 1904, being placed in charge of the testing department in 1905, and in 1906 becoming construction engineer on electrical apparatus for the company. In 1907, he became electrical inspector in the U.S. Navy Department. In 1911, he entered the employ of The Connecticut Company at New Haven, becoming assistant engineer in the engineering department, covering general electrical work in a street railway property operating in several cities in Connecticut. In 1917 he became electrical engineer for the company, holding this position until the time of his death, and being in responsible charge of electrical design and construction for the company.

Sumito Fukasawa (A'34) Tokyo, Japan, died December 31, 1934, according to information received recently at Institute headquarters. Mr. Fukasawa was born at Nagano-ken, Japan, October 19, 1905. He attended Iowa State College, Ames, receiving the degree of bachelor of science in electrical engineering in 1933. Previous to graduation, he spent several months as part time electrician at Guilford College,

N. C., and for a short time that year gained experience working as an assistant in the engine room of the Molly Pitcher Hotel, Red Bank, N. J. For a period starting in 1932, he was employed on work in the laboratory at Iowa State College. He recently had been engaged on the translation of an article on cable manufacturing.

David Rasmussen (A'26) electrical designer, Elliott Company, Ridgway, Pa., died during April 1935. Mr. Rasmussen was born at Oxford, Ind., on Oct. 10, 1901. He was a graduate of Purdue University, West Lafayette, Ind. Following one year, 1924–25, as student engineer for the Duquesne Light Company, Pittsburgh, Pa., he became design draftsman for the company in 1925. In 1929 he became electrical designer for the Elliott Company, having held that position since that time.

Membership

Applications for Election

Applications have been received at headquarters from the following candidates for election to membership in the Institute. If the applicant has applied for direct admission to a grade higher than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the national secretary before Aug. 31, 1935, or Oct. 31, 1935, if the applicant resides outside of the United States or Canada.

Bertero, G. A., Brooklyn Edison Co., Brooklyn, N. Y.
Clevenger, C. M., c/o A. H. Ferris Co., Los Angeles, Calif.
Doolittle, J. B., Southwestern Bell Tel. Co., Kansas City, Mo.
Enderlin, M., (Member) Gibbs & Hill, New York, N. Y.
Griffith, R. C., General Elec. Co., Schenectady, N. Y.
Hazard, C. R., 733 N. W. Everett St., Portland, Ore.
Hildebrandt, D. B. (Member), Consumers Pwr. Co., Muskegon Hgts., Mich.
Inclan, L., Mexican Lt. & Pwr. Co., Mexico City, Mex.
Kilgore, R. R., Lincoln Elec. Co., Cleveland, Ohio.
Klauder, L. T., Rural Electrification Administration, Washington, D. C.
Lewis, D. A. (Member) Empire Gas & Elec. Co., Geneva, N. Y.
Lincoln, E. W., United Carr Fastener Corp., Cambridge, Mass.
Lippmann, B. A., 1921—66th St., Brooklyn, N. Y.
Miller, C. E., General Elec. Co., Schenectady, N. Y.
Sauter, O., Franklin Engg. Corp., New York, N. Y.
Sawle, R. T., English Elec. Co., St. Catharines, Ont., Can.
Scheffler, H., Mexican Lt. & Pwr. Co., Mexico D. F., Mex.
Sherman, W., Utica Gas & Elec. Co., Utica, N. Y.
Stansbury, C., (Member) Cutler-Hammer Inc., Milwaukee, Wis.
Ward, H. A., Interborough Rapid Transit Co., New York, N. Y.
Zuschlag, T., Magnetic Analysis Corp., Long Island City, N. Y.

21 Domestic

Foreign

Britton, J. R., Hawaiian Elec. Co., Ltd., Honolulu, T. H.
Chellam, S. V., Hydro Elec. Dept., Meltur Project, So. India.
Chu, C. Y., Association of Chinese Public Utilities, Shanghai, China.
Deering, J. E., British Post Office, London, N. 1, England.
Keoylos, L. M., Am. Farm Sch., Salonica, Greece.
Lacarriere, C., Compagnie des Lampes, Courbevoie, Seine, France
Proctor, J. A. M., Demerara Bauxite Co., Mackenzie, British Guiana, So. Am.

7 Foreign

Addresses Wanted

A list of members whose mail has been returned by the postal authorities is given below, with the addresses as it now appears on the Institute record. Any member knowing of corrections to these addresses will kindly communicate them at once to the office of the secretary at 33 West 39th St., New York, N. Y.

Bauer, Charles, 9 Royalton Place, Bloomfield, N. J.
Bock, F. S., 1642 W. Broad St., Richmond, Va.
Chiofalo, J., 203 Graham Ave., Brooklyn, N. Y.
Ghosh, K. C., c/o Compagnia Generale Di Elettricita, 34 Via Borgognone, Milan, Italy.
Golikoff, A., Main P. O. Gen. Del., Moscow, U.S.S.R.
Greene, F. M., 656—50th St., Brooklyn, N. Y.
Haddad, Raphael A., 500 Riverside Drive, N. Y. City.
Kimball, Gordon S., 154 Elmer Ave., Schenectady, N. Y.
Martinoff, V. M., 2150 Queen St., Toronto, Ont., Can.
Nelson, Charles J., 1515 N. Lotus Ave., Chicago, Ill.
Rozelle, P. M., 2018 Chestnut St., Harrisburg, Pa.
Schellberg, Kenneth O., 4115—51st St., S., Seattle, Wash.
Schlosser, Walter H., Dominion Elec. Power, Ltd., Regina, Sask., Can.
Sillstrop, John P., Eldorado Towers, 300 Central Park West, New York, N. Y.
Smeaton, J. H., Rua Teixeira de Mello 49, Rio de Janeiro, Brazil, S. A.
Smedley, A. B., 82 Warner Ave., Hempstead, N. Y.
Vance, Paul E., c/o Marietta Mfg. Co., Point Pleasant, W. Va.
Verrier, E. J., Anglo Newfoundland Dev. Co., Grand Falls, Newfoundland.

18 Addresses Wanted

Engineering Literature

New Books in the Societies Library

Among the new books received at the Engineering Societies Library, New York, recently, are the following which have been selected because of their possible interest to the electrical engineer. Unless otherwise specified, books listed have been presented gratis by the publishers. The Institute assumes no responsibility for statements made in the following outlines, information for which is taken from the preface of the book in question.

CORROSION, CAUSES and PREVENTION. An Engineering Problem. By F. N. Speller. 2 ed. N. Y. and Lond., McGraw-Hill Book Co., 1935. 694 p., illus., 9x6 in., cloth, $7.00. A comprehensive review of the subject, especially with reference to the ferrous metals. The nature of corrosion, the influence of various factors, and the prevention of corrosion by air, water, steam, chemicals, and electricity are discussed.

DINAMOMASHINA V EE ISTORICHESKOM RAZVITII (Dynamo-Electric Machine in Its Historical Development). Documents and materials collected by D. V. Efremov and M. I. Radovskij; edited by V. Th. Mitkevitch, Academy of Sciences Press, Leningrad, 1934. 560 p., illus., 10x6 in., cloth, apply. Translations in Russian of the basic papers on the dynamo from 1832 to 1887.

A T M—Archiv für Technisches Messen. Lieferungen 39–44, Sept. 1934–Feb. 1935. Munich, R. Oldenbourg, illus., 12 x 8 in., paper, 1.50 rm. each. A review of methods and instruments use in technical measurements covering a wide field, classified and arranged so that the material may be collected in loose-leaf binders.

CUGLE'S TWO-MINUTE AZIMUTHS, Latitude 0° to 35°, Declination 0° to 23°, Same and Contrary Names. By C. H. Cugle. N. Y., E. P. Dutton & Co., 1935. 613 p., tables, 11x9 in. cloth, $5.00. By calculating this table to 2 minute intervals of time, the author has done away, in his opinion, with all necessity for interpolations in finding azimuths.

ANALYTISCHE GEOMETRIE der EBENE. (Sammlung Göschen 65.) By R. Haussner. 2 ed. Berlin and Leipzig, Walter de Gruyter & Co., 1934. 164 p., diagrs., 6 x 4 in., cloth, 1.62 rm. A brief introduction to plane analytic geometry, covering the usual undergraduate college course.

ANNUAL SURVEY of AMERICAN CHEMISTRY, v. 9, 1934. Ed. by C. J. West, National Research Council, N.Y., Reinhold Publishing Corp., 1935. 396 p., diagrs., 9x5 in., cloth, $4.50. A concise, comprehensive review of advances in pure and applied chemistry during 1934, including among the topics X-ray examination of materials and advances in electrochemical practice.

J. & P. TRANSFORMER BOOK being a Practical Technology of the Power Transformer. By S. A. Stigant and H. M. Lacey. 6 ed. Lond., Johnson & Phillips, 1935. 879 p., illus., 9x6 in., cloth, 12s 6d. A comprehensive exposition of power transformer theory and practice, designed to answer all the requirements of plant engineers. This edition has been revised and enlarged.

JOURNAL of the ROYAL TECHNICAL COLLEGE, v. 3, pt. 3, Jan. 1935, p. 339–526. Glasgow, Royal Technical College. Illus., 10x7 in., paper, 10s 6d. Records of research work recently carried out by the faculty and students of the college, including modifications of the cold-cathode Braun tube and stroboscopic examination of transitory torques.

Life and Letters of SEBASTIAN ZIANI de FERRANTI. By G. Ziani de Ferranti and R. Ince. Lond., Williams & Norgate, Ltd., 1934. 240 p., illus., 9x6 in., cloth, 12s 6d. This life of the noted pioneer electrical engineer is the work of his widow and his brother-in-law; many illustrations add to the interest.

MITTEILUNGEN aus den FORSCHUNGSANSTALTEN GHH-KONZERN, Bd. 3, Heft 8, April 1935. p. 199–222. Berlin, VDI-Verlag. illus., 12x8 in., paper, 2.70 rm. Includes a paper describing a new electric cable which is highly resistant to acid, alkalies, and other chemicals.

PRAKTISCHES HANDBUCH der GESAMTEN SHWEISSTECHNIK. Bd. 2. Elektrische Schweisstechnik. By P. Schimpke and H. A. Horn. 2 ed. Berlin, J. Springer, 1935. 274 p., illus., 9x6 in., lea., 15 rm. A comprehensive account of welding technique, covering arc, resistance, and gas-electric, electric soldering and cutting, weld testing, etc.

S O S to the RESCUE. By K. Baarslag. N. Y. Oxford Univ. Press, 1935. 310 p., illus., 8x6 in., cloth, $2.50. A description of the use made of radio in a number of major disasters at sea, 1909–34, which is an addition to the history of radio.

THEORY of VIBRATIONS for ENGINEERS, an Intermediate Course. By E. B. Cole. Lond., Crosby Lockwood & Son, 1935. 263 p., illus., 9x5 in., cloth, 15s. An intermediate course in which the physical meaning of the mathematical equations is stressed and special attention given to methods of practical utility to designers of high speed machinery.

HETCH HETCHY, ITS ORIGIN and HISTORY. By M. M. O'Shaughnessy. Newbegin's Book Shop, 358 Post St., San Francisco, Cal. 134 p., illus., 12x9 in., cloth, $5.00. An account of the project for supplying water to San Francisco, from its inception in 1901 to its completion in 1934. The actual construction from 1912 to 1934 was directed by Mr. O'Shaughnessy. The book was published in a small edition, of which 300 copies are for sale.

MECHANICS of MATERIALS. By S. G. George and E. W. Rettger. N. Y. and Lond., McGraw-Hill Book Co., 1935. 483 p., illus., 9x6 in., cloth, $3.75. A textbook covering the essential topics of a first course in this subject, intended for students of engineering. Numerous complete examples are introduced to illustrate the application of theory.

PRINCIPLES of QUANTUM MECHANICS. By P. A. M. Dirac. 2 ed. Oxford, Clarendon Press; N. Y., Oxford Univ. Press, 1935. 300 p., tables, 10x6 in., cloth, $6.00. The first edition in 1930 won recognition as a contribution to modern physical theory; the new edition has been largely rewritten and thoroughly revised, including a chapter on field theory.

STRUCTURE and PROPERTIES OF MATTER. By H. T. Briscoe. N. Y. and Lond., McGraw-Hill Book Co., 1935. 420 p., illus., 8x5 in., cloth, $3.55. An account of some of the facts and opinions concerning matter from the time of Aristotle to that of Bohr and Schroedinger, interpreting them from the point of view of the chemist.

TOOLS of TOMORROW. By J. N. Leonard. N. Y., Viking Press, 1935. 310 p., illus., 9x6 in., cloth, $3.00. A nontechnical discussion of modern developments in power resources and power distribution, the creation of new alloys, automatic machinery, and transportation and communication, and pointing to some lines along which striking progress may be expected.